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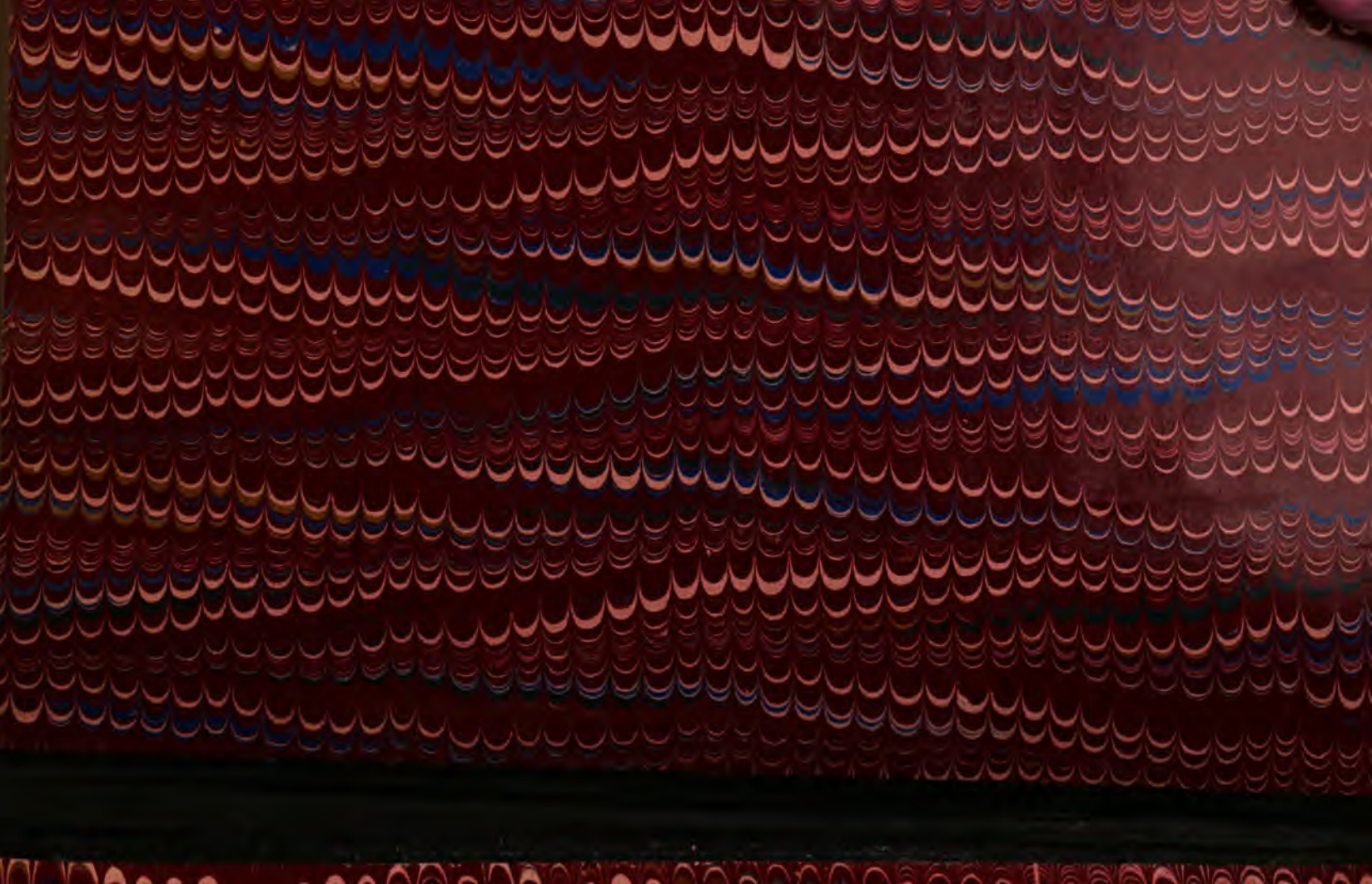

SHOP AND FOUNDRY PRACTICE

PREPARED FOR STUDENTS OF
THE INTERNATIONAL CORRESPONDENCE SCHOOLS
SCRANTON, PA.

Volume IV

PATTERNMAKING
FOUNDRY WORK
BLACKSMITHING AND FORGING

WITH PRACTICAL QUESTIONS AND EXAMPLES

Second Edition

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PATTERNMAKING.

(PART 1.)

GENERAL CONSIDERATION OF PATTERNMAKING.

INTRODUCTORY.

1. The production of ordinary metal castings, such as those of iron or brass, involves three distinct operations. First, a form is made very nearly like that required in the casting. This form is made of wood or some other easily shaped material, and is called the **pattern.** Next, from this pattern a mold is made in sand or in some other substance that is refractory enough to withstand the action of molten metal. Lastly, the metal is melted and poured into this mold. Each of these operations requires special skill, and has given rise to a special trade, though the latter two—the molding and founding—are often performed by the same person.

These operations are sometimes so intricate and admit of so much variety that the above statements are true only in the main. The molder may make his own pattern out of clay, or, if it should be necessary to use it a large number of times, he will make it of some hard metal; or he may make the mold itself, or a portion of it, of metal; and so on through a multiplicity of changes that are constantly occurring where a business is made of producing a variety of castings.

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Nevertheless, the main facts hold true, and the patternmaker is understood to be a wood worker, and the molder is one that makes the molds only, while the founder has charge of the furnace and melts the metals.

In the first of these operations, that of the patternmaker, there is needed a fair degree of skill in the arts of cabinetmaking and of wood turning, for patternmaking consists largely of fitting joints and making circular forms; consequently, the patternmaker must be familiar with the use of the tools of these trades.

PATTERNS AND CORE BOXES.

PATTERNS.

2. Definition of Pattern.—So-called patterns are often not actual patterns of required castings, therefore the following may be accepted as a definition of a pattern:

In connection with the foundry and machinery business, a pattern is understood to be a form by the use of which a mold may be made.

3. Materials Used in Patternmaking.—A pattern is usually made of wood, metal, rubber, or plaster. By far the most common are the wooden patterns because of the comparative cheapness of this material, the ease with which it may be given required shapes, its lightness, firmness, and the possibility of preparing its surface to withstand the action of the moist sand in the mold. The use of wood in making patterns is so nearly universal that the patternmaker is always understood to be a wood worker.

Where patterns are required to preserve their exact shapes during constant use, they are made of metal, by first preparing wooden patterns and finishing the castings obtained from these to be used as patterns. In making a wooden pattern for an iron pattern, it is necessary to make a double allowance for shrinkage.

CORES AND CORE BOXES.

4. Meaning of the Terms Core and Core Box.—When hollow castings are wanted, or castings with holes through them, it is customary to make a pattern of such form that it will leave a body of sand in the mold about which the metal will run. The body of sand left in the mold forms the desired hole or opening, as shown at *a*, Fig. 1. Such a body of sand projecting into the mold to form an opening in a casting is called a **core** and may be left by the pattern itself, as shown in Fig. 1, or it may be formed in a separate device, called a *core box*, and placed in the mold after the pattern is removed.

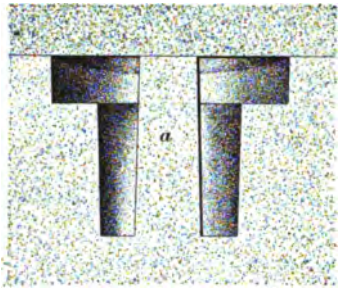


FIG. 1.

5. Core Boxes.—When it is not possible or when it is not convenient to have the cores left by the pattern, they may be formed in separate devices called **core boxes.**

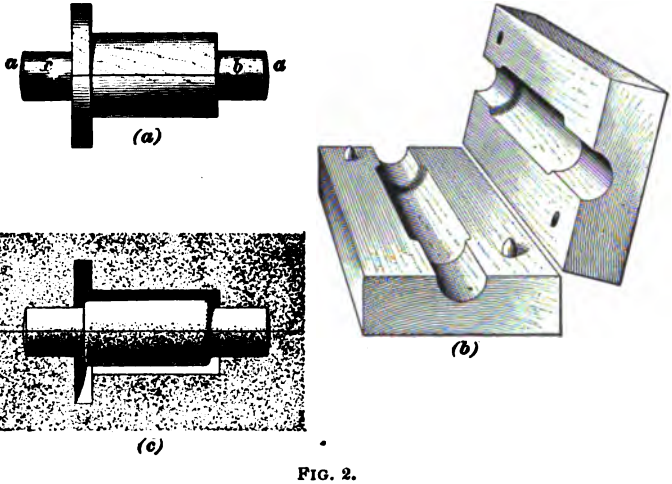


FIG. 2.

The core box is considered a part of the pattern, or patterns, with which it goes, the pattern and core box together forming a set. In Fig. 2 (*a*) is shown a pattern having *core prints b* and *c*. The core box for making the necessary core is shown in Fig. 2 (*b*) and the mold with the core in place is shown in Fig. 2 (*c*). It will be noticed that the ends of the core prints *b* and *c* are made tapered, as shown at *a*, so as to enable them to be withdrawn from the sand easily.

6. Metal Core Boxes. — When a large number of standard cores of the same size are required, as, for instance, the small cylindrical cores used in making holes through

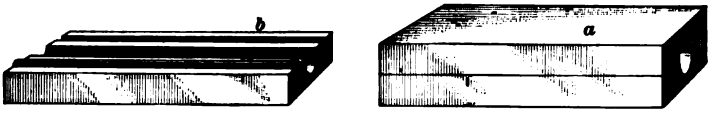
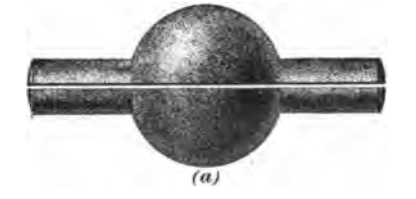


FIG. 3.

the hubs of pulleys, and in similar work, metal core boxes are employed, which may be purchased from supply houses. These are of standard sizes and are made of iron or brass.



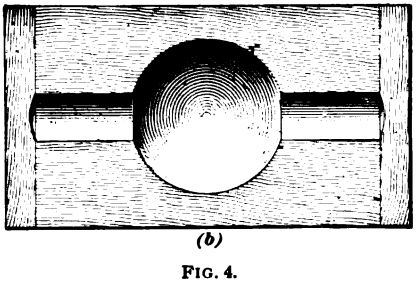


FIG. 4.

One form of metal core box is shown in Fig. 3. At *a* both portions of the core box are shown together, while at *b* one half of the box is shown, illustrating the manner in which the halves are joined together by means of two long tongues and grooves.

7. Partial Core Boxes.—Very often in the case of symmetrical cores, the box is made for a portion of the core

only. In the case of cylindrical cores, only half boxes need be made, and two of the cores from such a box may be pasted together, as shown in Fig. 4 (*a*). Fig. 4 (*b*) shows the box in which the half cores were made.

This same principle may be used in the case of very heavy work, as, for instance, the rims of flywheels, which may be formed by placing large cores in the mold. In fact, sometimes a symmetrical mold like a flywheel is built up almost entirely from cores.

Core boxes require as great care in their manufacture as patterns, and as much thought must be given to their shape, durability, and finish. The shape of the pattern is nearly like that of the required casting, except that it may have no holes in it. The openings in the core box resemble the openings in the casting.

8. Use of Burning Irons.—Where small holes are required in patterns that are intended to form their own cores, they are frequently formed by means of **burning irons.** This is resorted to especially in the case of small vertical cores. The burning irons are round or square, according to the shape of the hole desired, and are given a great deal of taper lengthwise, about 1 inch in 9 inches. They should be finished evenly on their surfaces and not heated above a cherry red when in use.

CORE PRINTS.

9. General Consideration.—When the cores are made in boxes and inserted in the mold, it is necessary that they should be supported in such a manner that there will be no chance for a change of position during the time the mold is being filled with the molten metal. To give the cores this support, special recesses are made in the mold to receive them. These recesses are made by attaching pieces called **core prints** to the pattern, as shown at *a* and *b*, Fig. 5 (*a*).

10. Core prints are usually colored differently from the rest of the pattern so that the molder may easily distinguish where the cores are to be placed. As cores are always a source of more or less trouble in a mold, the print should be made of such a shape and size as will give the least inconvenience to the molder. The core should exactly fill the recess left by the print, and the core print should be of such a size that the recess left in the sand will not be crushed out of shape by the weight of the core or the action

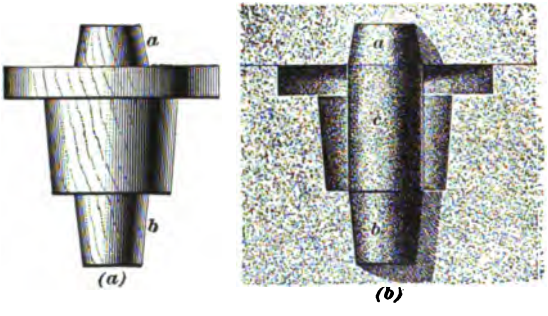


FIG. 5.

of the molten metal. Core prints should be tapered, so that the trouble of withdrawing the pattern from the sand may not be increased by their presence, and also that a core may be easily adjusted in place. Prints for vertical cores should be tapered in their length, and some patternmakers prefer to give the most taper to the upper core print, as shown at *a*, Fig. 5 (*a*). In Fig. 5 (*b*) is shown a mold made by the pattern illustrated in Fig. 5 (*a*). The ends of the core *c* fit in the recesses left by the core print, as shown at *a* and *b*. Some patternmakers make the lower print almost parallel and of the same diameter as the core, so that different lengths of core can be made in the same box.

11. Standard Core Prints and Hubs.—It is always best to adopt a standard system for core prints, especially for those intended for vertical cores. These core prints may be turned up in pairs, having small projections on them

that act as dowel-pins to locate them correctly in the hubs. Fig. 6 illustrates a set of core prints ranging from $\frac{1}{2}$ inch to 2 inches in diameter at the large end, and all having $\frac{7}{16}$-inch pins for locating them.

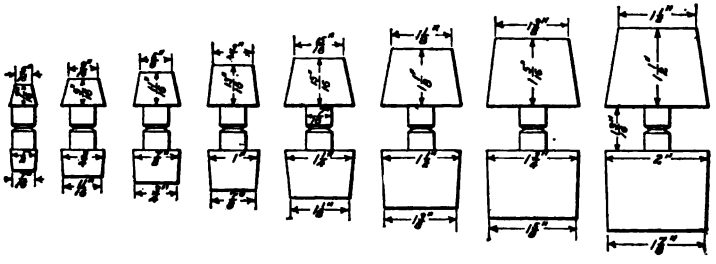


FIG. 6.

In like manner, the hubs required on pulleys and gears should be reduced to a standard, and Fig. 7 shows four standard hubs arranged according to such a system. It will be noticed that each hub has a $\frac{7}{16}$-inch hole in one face to receive the pin on the core print, while on the opposite face

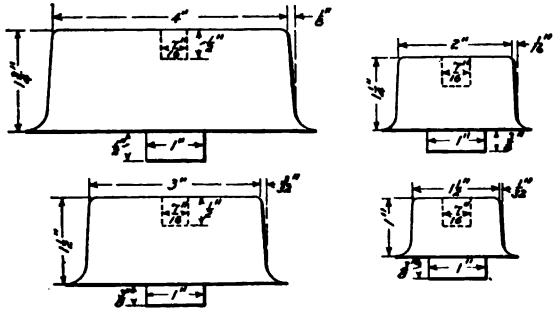


FIG. 7.

there is a 1-inch pin that fits into the pattern and locates the hub. By adopting such a series of standards as this, it is very easy to change the size of hub or core in gears or pulleys within quite a wide range, and thus make the regular patterns that the shop may have available for a much wider range.

12. Special Core Prints.—Very often the shape of the core print is changed to fit some condition in the molding; as, for instance, in Fig. 8, *a* illustrates a required casting in which the core is some distance from either face. In order to support the ends of the core, the prints are made of a special form, as shown on the pattern at *b*. It

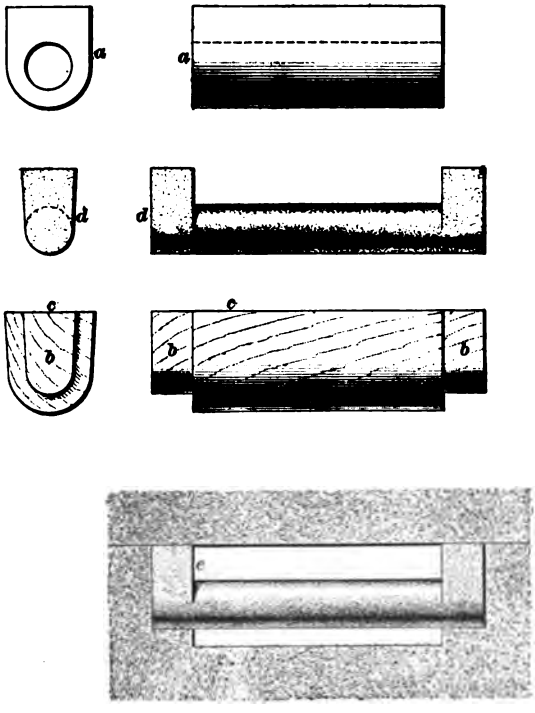


FIG. 8.

will be noticed that the prints have been carried to the upper face *c* of the pattern. The core is made in a special core box, so that it has end projections, or lugs, that will fit the special prints formed. The completed core is shown at *d*, and at *e* the core is shown in place in the mold.

At other times, it becomes necessary to introduce a core that does not pass entirely through the work, and that

might have a tendency to fall down in the mold. A pattern for such a piece is shown in Fig. 9. The core print *a* is made long so that when the core is in place, a little more than half of it will rest in the portion of the mold formed by the print. By having the core print a very little smaller in diameter than the core, the mold will pinch the core and hold it so firmly that there is no danger of its slipping out into the mold.

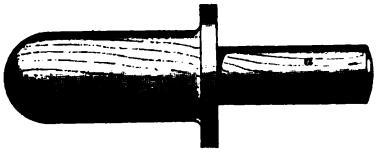


FIG. 9.

MATERIALS EMPLOYED IN PATTERNMAKING.

WOOD.

13. Relation Between Number of Castings and Character of Pattern.—The cost of a pattern or the amount of work bestowed on it should depend on the number of castings to be made. When but one casting is wanted and the pattern is not likely to be required again, the pattern or device required for making the mold should be as inexpensive as possible, both as regards labor and material. To fulfil this requirement, skeleton patterns, or part patterns in the case of symmetrical work, are very largely used, and these will be described in detail later.

Standard patterns, or those that are often used, should be made with great care, always having in mind that the cost of the casting depends as much on the pattern as on the work of the molder. If the molder must patch up each mold on account of the fault of a cheaply made pattern, it would pay to destroy such a pattern and make a better one, if there were no other remedy for the trouble.

14. General Characteristics of Wood.—For patternmaking, clear, dry, white pine has generally been found

to be the most suitable material. Occasionally, when a large number of castings is required from a small pattern, it is made of hard wood, such as mahogany or cherry.

One of the difficulties with which wood workers have to contend is the change in shape due to the warping and shrinking of the wood. As pine is the chief material used for patternmaking, a brief study of its nature and the reasons for its warping is here taken up. Fig. 10 illustrates a section of a log. It will be noticed that the end grain shows a series of concentric rings. The number of these rings corresponds approximately to the number of years that the tree has lived. Running at right angles to these rings are other lines commonly called *medullary*, or *silver*, *rays*. All logs are also composed of two parts, called the *sap-wood* and the *heart-wood*. The sap-wood is the more recent growth and forms a comparatively thin layer at the outside of the log. It is usually not so firm as the heart-wood, but is more liable to change its shape and to decay, hence its use should be avoided whenever possible.

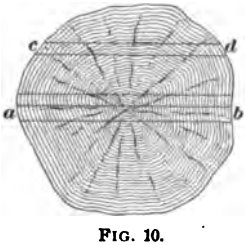


FIG. 10.

15. Microscopic Section of Wood.—Fig. 11 illustrates a microscopic section of pine wood magnified seventy-six times. The dark line of cells from *b* to *c* indicates the line between two of the concentric rings of the tree. In the portion *b d c*, it will be noticed that the cells are large and open. This represents the summer growth. In the portion *b c f e*, the cells are small and close. This portion represents the fall and winter growth, while the portion *e f g* represents the spring and summer growth. The large opening at *a* is a resin duct. The small spaces enclosed by the cell walls are filled principally with water, which must be almost entirely driven out before the wood is fit to use in making patterns. As the water leaves the wood, the cell walls shrivel slowly and the wood as a whole shrinks, this shrinkage taking place mostly across the grain of the wood.

The amount of shrinkage along the grain is so small that it need not be considered. This driving out of the moisture and the consequent shrinkage of the wood is called *seasoning*.

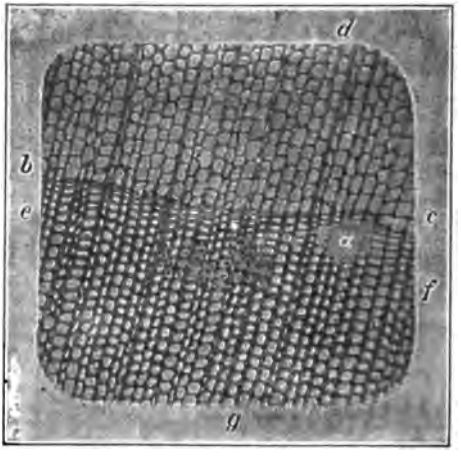


FIG. 11.

16. Seasoning Wood. — Wood intended for pattern-making should be well seasoned; that is, it should be kiln-dried, or kept from one to two years before using, according to the thickness of the pieces. This seasoning helps considerably in preventing a piece of wood from warping, but though this precaution be taken and the wood well seasoned, unless it is coated with some protecting agent, it will still be subject to change, owing to atmospheric changes, for it will absorb moisture in damp weather and give it up in warm and dry weather.

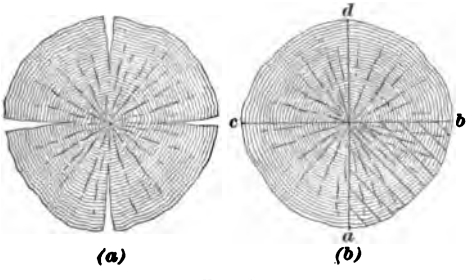


FIG. 12.

17. Laws Governing Warping and Cracking of Wood.—The workman has little control over the shrinking and swelling of wood that is unprotected; but there are certain conditions that tend to warp a piece from its original shape, a study of which will enable the patternmaker to overcome the difficulties to a considerable extent. As has already been stated, Fig. 10 represents a cross-section of

a log of wood showing the annular rings. If the tree is cut when the microscopic cells shown in Fig. 11 are full of sap or moisture and is then allowed to dry, it is probable that the log will split from the outside toward the center, as shown in Fig. 12 (*a*). It will be noticed that this cracking takes place across the annular rings, but parallel to the medullary rays, and it may be stated that this is true in practically all cases.

18. If a board were to be sawed very near the heart of a log, as shown at *a b*, Fig. 10, it would not have a great tendency to warp, but would remain approximately straight, as shown at *a*, Fig. 13, while if a board were sawed from the log at some distance from the heart, or center, of the log, as shown at *c d*, Fig. 10, it would have a tendency to warp, as shown at *b*, Fig. 13; that is, the wood would draw together at right angles to the medullary rays, thus throwing up the outer corners. By taking advantage of this fact and selecting lumber from comparatively near the heart, the tendency to warp can be reduced.

FIG. 13.

19. Quarter-Sawing.—In order to reduce the tendency to warp by having the boards practically all sawed at nearly right angles to the annular rings, **quarter-sawing** is sometimes resorted to. In this case a log is sawed into four pieces, as indicated by the lines *b c* and *a d*, Fig. 12 (*b*). Each piece is then laid back down and sawed into boards, as indicated by the lines in the quarter between *a* and *b*. This method is wasteful in lumber, but reduces warping to a minimum and in certain kinds of wood produces very beautiful results on account of the manner in which it intersects the medullary rays.

20. Gluing as a Means for Overcoming Changes of Shape.—The tendency of lumber to warp can be partially overcome by properly gluing the pieces. For instance, the plank shown at *b*, Fig. 13, could be sawed into pieces as shown at *c*, the adjacent pieces laid in opposite directions

and glued together, as shown. This would reduce the total tendency to warp to a minimum by causing the adjacent pieces to warp in opposite directions and within comparatively narrow limits. Sometimes a large solid piece that will not warp is needed in patternmaking. Of course, it is absolutely impossible to get one that will not warp at all, but by gluing several planks together, as shown in Fig. 14 (*a*), this tendency is greatly reduced. It will be noticed that the boards or planks have been laid in reversed directions, that is, so that one board will have a tendency to warp toward the other. It is not, as a rule, good practice to lay the planks together in such a manner that the grain of one piece is at right angles to that of the other, as shown in Fig. 14 (*b*), for when this is done, the pieces *a* and *b* will shrink in such a way as to leave the ends of *c* and *d* projecting on the sides of the piece, while at the front and back ends the pieces *a* and *b* will project. In other words, each plank would shrink the most across its grain and it would be practically impossible to keep the surface of the block smooth. Of course, this tendency is largely overcome by covering the pattern with a coat of paint or varnish.

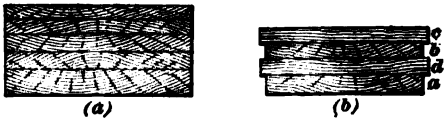


FIG. 14.

METAL AND OTHER MATERIALS USED FOR MAKING PATTERNS.

21. Special Patterns. — Special patterns are often made of iron, brass, white metal, and aluminum. With a few exceptions, original patterns are all made of wood. Ornamental work and statuary are usually modeled in wax or clay.

Rubber patterns are made from vulcanized india rubber. These may be prepared by first taking enough sulphur to equal 15 per cent. of the weight of the rubber and dissolving it in oil of turpentine and then dissolving the rubber in this mixture and allowing the oil to evaporate. After the

oil has evaporated, the mixture of sulphur and rubber may be pressed into molds made of metal or plaster and vulcanized by submitting it to the action of steam at a temperature of 280° F., or, as it is usually done, putting it in a closed vessel and admitting steam at a pressure of about 50 pounds or a little more. If the temperature is increased (by increasing the steam pressure), the pattern may be made harder. These patterns are especially adapted to light match-board work, the objection to them being the trouble of making them.

SANDPAPER.

22. Sandpaper is composed, as its name implies, of sharp sand (quartz or garnet) glued on paper. It can be had in rolls or sheets, the most convenient size for patternmaking being the sheets, 9 inches by 11 inches. In patternmaking, sandpaper should be used with great care; the patterns should be formed as nearly to shape and size and finished as accurately as possible with the tools, sandpaper being used only for giving a finish, as otherwise the draft and accuracy of the pattern may be destroyed. The kind of pattern determines the fineness of the sandpaper to be used and character of finish required; usually from No. 00 to No. 1½ are the grades employed in this class of work. Under no circumstances should sandpaper be used for cutting down or removing any considerable amount of stock, or for doing anything that may be done with tools.

FASTENINGS USED IN PATTERNMAKING.

METAL FASTENINGS.

23. Nails.—The **nails** most commonly used in patternmaking are the bung-head steel-wire nails, as they have less tendency to split the wood than the tapered cut nails. The sizes of nails to be kept in stock in a pattern shop doing a general class of work are as follows: No. 20, ⅞ inch,

½ inch, ⅝ inch; No. 18, ¾ inch, ⅞ inch, 1 inch; No. 16, 1¼ inches, 1½ inches; No. 14, 2 inches; No. 12, 2½ inches; No. 11, 3 inches.

The nails should be kept separate and in good order, as this saves much time. Every patternmaker should have a nail box with compartments for the various sizes, for, if they become mixed, much valuable time will be lost in searching for the required size.

SCREWS.

24. Owing to the necessity for hammering patterns when drawing them from the sand, it is always best to use **screws** instead of nails in securing the parts of a pattern. The use of screws also facilitates the altering of patterns whenever it becomes necessary. The sizes of screws required in general pattern work are as follows: No. 5, ½ inch, ¾ inch, 1 inch; No. 8, ¾ inch, 1 inch, 1¼ inches; No. 10, 1 inch, 1¼ inches, 1½ inches; No. 12, 1½ inches, 1¾ inches, 2 inches, 2½ inches; No. 16, 2¾ inches, 3 inches, 3½ inches, 4 inches.

The screws should be kept in drawers, or in a case having proper compartments, and each size should be labeled. It will be noticed that the numbers designating the sizes of the nails run in a direction opposite to those designating the sizes of the screws; i. e., the larger the nail is in diameter, the smaller is the number by which it is designated, while, with screws, the larger the diameter of the screw, the larger is the number that designates it.

ADHESIVE FASTENINGS AND PROTECTIVE COATINGS.

GLUE.

25. Character of Glue.—In patternmaking, **glue** is usually depended on for adhesive fastening, though at times small parts or fillets may be secured by means of varnish. Much depends on the character of the glue used in patternmaking, because many patterns cannot be nailed or screwed,

and, as they must be held together while being subjected to the action of damp sand, it is essential that only first-class glue be employed. There are many qualities of glue on the market, including liquid, pulverized, and sheet. The liquid glue is good in quality and very handy for small work, as it is always ready for use. The sheet, or flake form, dissolved and used hot is, however, preferred for general work. Animal glue is the best; it comes in thin sheets and is the most expensive. As a rule, the best quality of glue is of amber color, and the flakes are rather thin. Glue should be soaked in cold water before placing it in the glue pot, but the soaking should never be continued for a great length of time, as this injures the quality. Glue is strongest when freshly prepared, and, if of good quality, may be drawn out into very thin threads. As a rule, the harder the glue, the better it will resist moisture.

26. Glue Pot.—Glue should be used while hot, and that it may be kept in this condition without danger of burning, some form of **glue pot** becomes a necessity. The glue pot is usually water-jacketed; that is, it is surrounded with hot water. Fig. 15 shows a very common and handy

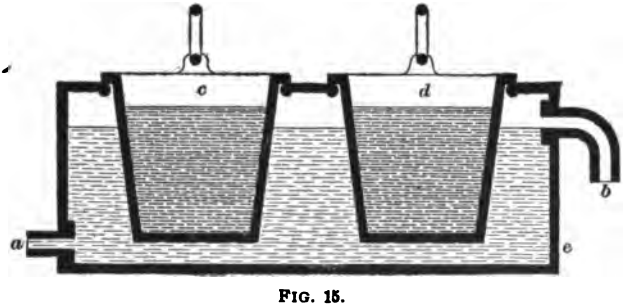


FIG. 15.

device. The two glue pots *c* and *d* are so supported that they rest in a bath of hot water in a vessel *e*. A very small stream of steam is introduced through the pipe *a* and the condensed water gradually escapes through the pipe *b*. This device keeps the glue constantly warm and ready for use.

27. Glue Brushes.—Glue is usually applied with an ordinary paint brush, though in cases where a patternmaker can obtain pieces of basswood bark, he can make his own **glue brushes** very cheaply. The desired form is cut out of the basswood bark; the brush end is then soaked in hot water and hammered until it becomes soft. Owing to the fibrous nature of the basswood bark, it makes a very soft and fine brush, but these brushes are usually rather short-lived.

28. Precautions Necessary in Gluing.—In gluing two pieces together, the hot glue should be thin enough to spread easily; and if the surfaces to be glued are hot or warm, a better joint may be obtained. Before applying glue to any surface, the latter should be wiped clean of any dust. This is especially true in the case of surfaces that have been prepared by sandpaper, for, in this case, the dust has probably been rubbed into the pores of the wood and so would not allow the entrance of the glue into these pores.

When the end grain of wood must be glued, it is best to give the material a sizing coat first. That is, the end of the grain is coated with glue to fill the openings among the fibers. After the glue has dried, the surfaces are given another coat and are then united. If this is not done, the open grain of the end is liable to absorb the glue so rapidly as to weaken the joint. Immediately after the glue is put on any pieces that are to be glued together, they should be pressed firmly together with clamps and held in this manner while the glue is setting. Plenty of time should be given for the glue to set; in most cases, 10 to 12 hours in a dry place is sufficient.

PATTERN VARNISH.

29. General Consideration of Pattern Varnishes.—All wooden patterns should be covered with some protective coating so as to prevent warping and cracking from the influence of the moist sand in the mold, and to

prevent the glued joints from coming apart. This protective coating is also made of such a nature that it is not affected by moisture and insures a smooth surface that draws easily from the sand. In practice, there are two general classes of **pattern varnishes.** The first is composed of *shellac*, with or without some coloring ingredient. The second comprises the better grades of *copal varnishes*, which may also be colored. By changing the color of the varnish used for this protective coating, it is possible to distinguish between core prints and the main body of the pattern, and also between patterns for different purposes; as, for instance, patterns for brass, iron, steel castings, etc.

30. Yellow Shellac Varnish.—Shellac varnish is the most common protective coating used for patterns. It is made by dissolving gum shellac in alcohol. The orange shellac, which comes in thin plates, is employed for this purpose, the white shellac being more expensive and not as well suited to the work of the patternmaker. The shellac varnish is commonly called *yellow varnish.*

Gum shellac may be dissolved either in wood (methyl) alcohol, or in grain (ethyl) alcohol. The grade of shellac used should be good, as it is not economy to buy cheap material for this purpose, on account of the fact that it will not stand up to the work as long as a better grade. Care should be taken not to use mixed wood and grain alcohol with shellac, as it will form a varnish that does not dry quickly and is more easily affected by moisture.

31. Frequently, yellow varnish changes to a muddy color by leaving the cover off the varnish pot, or from other causes. Such varnish may be restored by stirring a little powdered oxalic acid into it.

NOTE.—Varnish that has been cleared by the use of oxalic acid should never be used on a cut finger, as it is poisonous; in fact, the use of shellac as a protective covering on cuts and bruises is always more or less dangerous, for, while the alcohol kills the germs, the varnish is liable to have foreign substances in it that may be introduced into a wound and thus cause blood poisoning. Wood alcohol is always

poisonous if taken into the system. For these reasons, it is best to prohibit entirely the use of shellac for this purpose.

32. Black Shellac Varnish.—Black shellac varnish may be made by adding lampblack to the yellow shellac. The lampblack employed should be of the finest quality and free from grit. The quality may be tested by rubbing a little of the material between the thumb and finger, when no grit whatever should be felt. A better grade of black varnish may be made by dissolving black aniline in shellac. Only the brand of aniline soluble in alcohol can be used.

33. Red Shellac Varnish.—This varnish may be made by adding red powder, usually Indian red, to yellow shellac. The use of either lampblack or red powder in shellac seems to give it a better body and greater durability.

34. Copal Varnishes.—Copal varnish is very much like shellac in color, though it usually has a slightly greater luster. The objection to copal varnish is that it is very slow in drying, compared with the shellac varnishes prepared with alcohol. Black and red varnishes may be made from yellow copal varnish by adding lampblack or red powder. Where there is plenty of time available in the making of patterns, and the patterns are to undergo hard service, it is best to employ the better grades of copal varnish, for, while it is slightly more expensive and takes longer to dry, it is very much more durable and will outlast several coats of shellac.

35. Application of Varnish.—In applying the varnish, the pattern should be wiped clean and free from dust. This is especially necessary if the surface has been finished by sandpapering. The first coat of varnish should be a liberal one, applied smoothly, and allowed to soak well into the pattern. When the varnish is thoroughly dry, the pattern will feel rough to the touch on account of the fact that the varnish has hardened any projecting particles or loose grains of the wood. The first coat of varnish should be rubbed smooth with a well-worn piece of fine sandpaper, care being taken not to disturb the general surface any more than is

possible. The pattern should then be wiped free from dust and given another coat of varnish, the second coat being lighter than the first. After the second coat is dry, the pattern is again rubbed down and given another coat, this process being repeated until the desired surface is obtained, or until sufficient coating has been applied to render the pattern impervious to moisture. With yellow shellac varnish, three coats are usually enough. Several thin coats are better than a small number of thick coats, but, of course, the use of thin coats requires more labor.

36. When patterns become rough from use in the foundry, they should be cleaned and varnished, for if the pattern is smooth and well finished, it will give the molder but little trouble, and, hence, will not receive such hard usage. If the pattern is rough, the molder must rap and jar it a great deal in order to insure its drawing properly, and this treatment frequently injures it.

37. Varnish Brushes and Varnish Cans.—Pattern varnish can be best applied with a fine flat bristle brush. A new brush should be kept in alcohol some time before using, and when the brush is not in use, it should be kept either in the varnish or in alcohol. Yellow varnish is usually best kept in an earthenware jar or mug, on account of the fact that metal will discolor it.

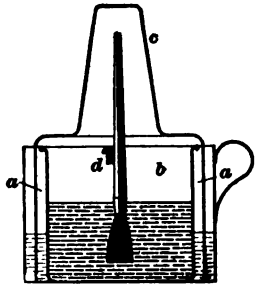


FIG. 16.

Fig. 16 illustrates a very handy form of can for keeping black varnish. The can proper is made double, the varnish being kept in the inner portion *b*, while the annular space *a* is partially filled with water. The cover *c* fits into the water space, thus sealing the varnish airtight and yet removing all danger of the cover sticking to the varnish pot. The brush is kept suspended by means of a hook on a rod *d*, the rod being also useful for cleaning the brush.

FILLETS.

38. Necessity for Round Corners in Castings.— Sharp corners, whether inside or outside of a pattern, should be avoided, and whenever there is nothing to interfere, all corners should be rounded. Sharp corners on the inside of a pattern form sharp corners of sand when molding, and these give the molder a great deal of trouble. Sharp corners, as a rule, detract greatly from the appearance of a casting, and also injure its strength. This weakness due to sharp corners is shown by the three illustrations in Fig. 17. At (*a*) is represented a casting having a sharp

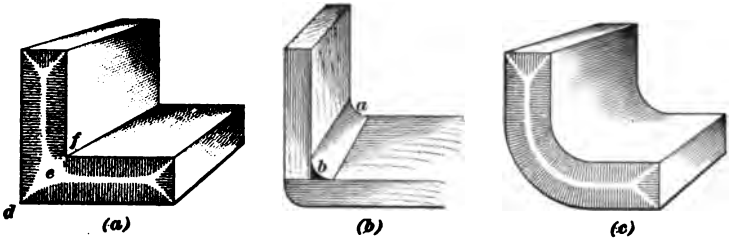


FIG. 17.

corner. As the iron hardens, the crystals seem to form in such a manner that their lines of strength are perpendicular to the faces, as indicated by the lines in Fig. 17 (*a*). This will leave an open space, or a space of irregular crystallization, at *e*, and the casting is liable to break along the line *df*. To overcome this, a **fillet** is usually placed on the inner corner, as shown at Fig. 17 (*b*), *a b* being the fillet. The outside corner of the pattern is also rounded, as shown. Fig. 17 (*c*) shows a casting from a pattern having a carefully rounded corner, and it will be noticed that there is no open space of irregular crystallization as occurred at *e*, Fig. 17 (*a*).

39. A good illustration of the faulty results that may arise from sharp corners is shown in the two cylinders represented in Fig. 18. The one at (*a*) was cast with sharp corners and a square bottom. If pressure is brought upon

the interior of the cylinder, the head *h* will be forced out, as shown in the illustration, the break occurring along the lines *de* and *fg*. If the cylinder had been cast, as shown in Fig. 18 (*b*), with a round end, one portion of it would be as liable to break as another, and, in fact, the end would be the strongest part of the cylinder. Fillets for patterns may be made of leather, wood, metal, wax, or any suitable material that can be worked into the desired form.

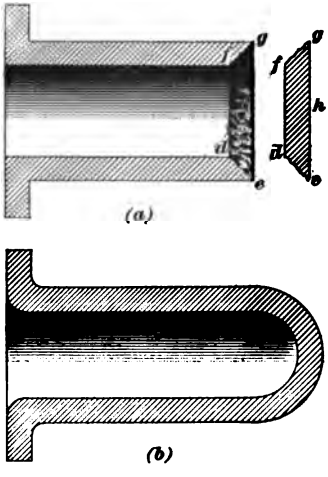


FIG. 18.

40. Wooden Fillets.—Wooden fillets are usually employed only in straight corners, and it is often better to glue a square or triangular strip in place and hollow it to the desired curve after the glue is dry. The advantage of this procedure is that thin edges are not so liable to curl up as they are if it is attempted to glue a wooden fillet of the desired shape into place.

41. Leather Fillets.—Leather makes the best material for fillets on account of the fact that such fillets can be applied to any form of corner, no matter whether straight or curved, or no matter how irregular the curve may be; also, the leather is light, durable, and neat. Leather fillets may be made by cutting shavings from leather with a plane of the form shown in Fig. 19, but it is best to buy the fillets ready cut from some firm that makes a business of supplying them, on account of the fact that a much more uniform

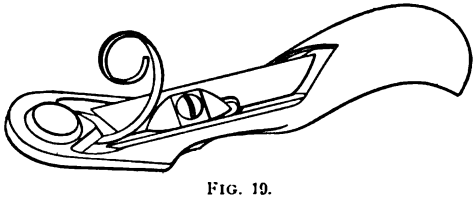


FIG. 19.

product may be obtained. Fig. 20 shows a set of such standard leather fillets.

42. Wax Fillets.—Beeswax is used for making small fillets, but much of the beeswax of commerce is so adulterated with tallow that it is difficult to obtain a satisfactory grade. It is also used for filling nail holes, etc. A good substitute for beeswax is made by mixing whiting,

FIG. 20.

resin, and linseed oil with beeswax in the following proportions: 1 pint of linseed oil, 4 pounds of beeswax, 4 pounds of whiting, and ½ pound of resin. This mixture should be made in a pot similar to a glue pot, and should be used when warm, as it becomes hard when cold. Nail holes in patterns are sometimes filled with common putty, which is a mixture of whiting and linseed oil.

43. Wax is also used for coating iron patterns to prevent their rusting, and to allow them to be drawn from the mold easily. To apply wax to an iron pattern, the pattern is first polished and then washed with a dilute solution of sal ammoniac, which will coat it with rust. The pattern is then warmed until it will melt the wax, and the wax rubbed over it. It is usually best to brush the hot wax with a soft brush so as to distribute it evenly.

44. Metal Fillets.—Metal fillets of a form similar to the leather fillets shown in Fig. 20 have been made and are on the market, but in the case of patterns that are to receive rough usage, they are not usually successful, owing to the fact that the rapping of the pattern jars the fillet loose, the metal stretching and hanging loosely on the nails, or other fastenings.

DOWELS.

45. Wooden Dowels.—Wood is the material most commonly employed for making dowel-pins, which are intended to keep the separate portions of patterns or core boxes in their proper relation to one another. The wood for this purpose is placed on the market in sticks of the required diameter, and all that the pattern-maker has to do is to point the dowel and cut it to the right length. The objections to wooden dowels are that the dowel-pins swell on exposure to moisture and, also, the holes in which they fit may close in owing to moisture. This causes trouble in the foundry, and to overcome it, the molder often whittles the point down too small or makes the hole too large, thus allowing the pattern to shift sidewise.

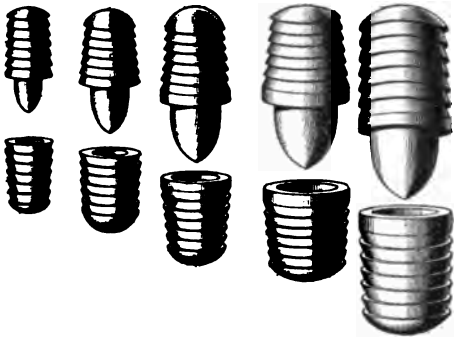


FIG. 21.

46. Metal Dowels.—To overcome the difficulties arising from wooden dowels, various forms of metal dowels have been brought out. Brass dowels seem to give the greatest satisfaction, on account of the fact that they do not rust. Fig. 21 illustrates a set of solid brass dowels turned from bars and intended simply to be driven into holes drilled in the pattern. Fig. 22 illustrates a similar set of brass dowels in which the points are made of smaller material than the sockets into which they are to fit. Either one of these forms

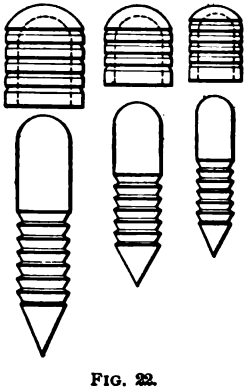


FIG. 22.

is very satisfactory for light work on small patterns. Fig. 23 illustrates a dowel pressed from sheet brass and intended for screwing to the face of a pattern. These are for use on medium-sized work. Fig. 24 illustrates a cast-iron dowel and plate intended for use on large or heavy patterns. The methods of inserting these dowels in the patterns will be

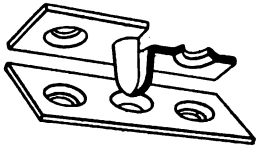


FIG. 23.

FIG. 24.

considered later. One great advantage in the use of any regular system of dowels is that it insures uniformity, and it is possible to replace a lost pin or socket without any difficulty, while in some cases, one part of a pattern may be made to serve with several other patterns by simply arranging it so that it may be doweled to any one of them.

PROVISION FOR RAPPING AND DRAWING PATTERNS.

47. Rapping and Drawing Plates and Rods.— To aid in the rapping and withdrawing of a pattern from the sand, it should be fitted with iron or steel plates. These

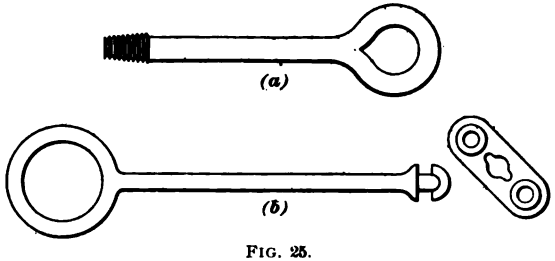


FIG. 25.

plates are sunk into the pattern, and are provided with suitable holes for rapping and lifting the pattern.

In the case of large patterns, two or more holes are provided in each plate. One is usually threaded to receive a draw-rod similar to that shown in Fig. 25 (*a*), and the other hole or holes are used for inserting pins by means of which to rap or shake the pattern so as to loosen it in the sand. Sometimes the lifting plates and the rapping plates are made separate, and, in the case of very large patterns, the rapping plates may be of considerable size so that a sledge or heavy mallet may be used on them. Such large plates should be made of wrought iron or steel.

48. Sometimes, to avoid the difficulty arising from the use of screw threads, lifting plates similar to those shown in Fig. 25 (*b*) are employed. The lifting rod has a key on the end, which is inserted into a slot in the plate and then given a quarter turn before lifting the pattern. Fig. 26 illustrates two forms of rapping plates, both of which can be let into the pattern entirely by boring. In the case of

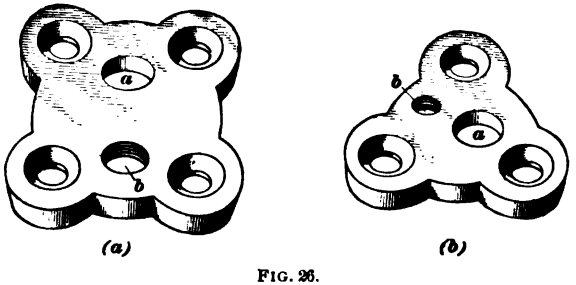


FIG. 26.

Fig. 26 (*a*), four small holes are bored to receive the ears that carry the screws, and then one large hole, cutting away about half of the previously bored holes, is drilled with an expansion bit to receive the balance of the plate. In Fig. 26 (*b*), there are only three ears carrying the screw holes. In both views, *a* represents the hole intended for the rapping pin and *b* the thread hole for the lifting rod.

When using plates of the form shown in Fig. 26, it is a good idea to take a blank plate of the exact outline of the one used and insert pins opposite the center of each circle. These pins are sharpened and allowed to project about

⅛ inch. By placing this plate upon the pattern and giving it a rap with a hammer, the pins will mark the centers of the holes that must be bored to locate the plate.

The location of rapping and drawing plates should be made a matter of considerable study; for, when the pattern is supported by the drawing irons, it should be well balanced, and usually the most effective rapping can be done from a point over the center of gravity of the pattern.

49. Draw-Nail.—When rapping and drawing plates are not used, as in the case of small patterns, the molder usually drives a small, sharp spike into the pattern for use in loosening the pattern by rapping against it; and, also, for drawing the pattern from the mold. The use of a **draw-nail** tends to destroy the pattern and should only be used when a comparatively small number of castings are required from a rather small pattern.

PATTERN LETTERS AND FIGURES.

50. Letters Made From Soft Alloys.—In order to enable the manufacturer to keep track of the castings and patterns, it is common to place certain letters and figures on them; these may be recorded, and serve to designate the

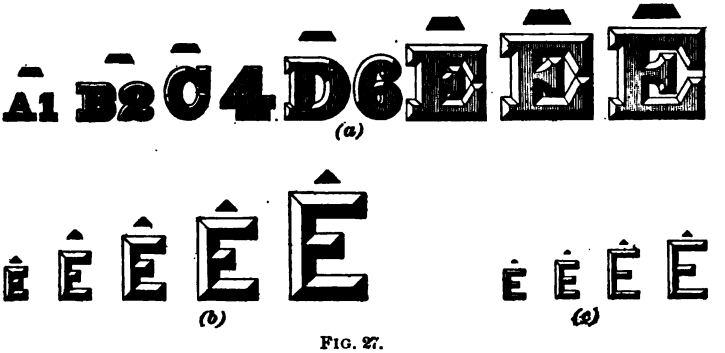


FIG. 27.

different pieces. Letters are also used for placing the manufacturer's name on patterns for advertising purposes. The letters most commonly used for this purpose are made from

an alloy of lead and tin, and the sides of the letters are given plenty of draft. The styles of letters most commonly employed are Roman and sharp Gothic. The thickness of the letter depends, to a considerable extent, on the size. Fig. 27 (*a*) shows examples of several sizes of Roman letters and figures. Fig. 27 (*b*) shows the ordinary sharp Gothic letters, while Fig. 27 (*c*) illustrates the hair-line sharp Gothic. These letters are often used in making name plates to be fastened to castings.

51. The Roman style of letters is best suited for advertising purposes on castings, as the tops of the letters have a larger area than the Gothic and so present a better appearance when polished. The sharp Gothic letters are best for marking patterns for the purpose of recording and ordering castings, on account of the fact that their sharp beveled sides have a larger amount of draft than the Roman letters, and, hence, will leave the sand more freely.

52. The hair-line Gothic style of letters is employed for making the letters on the dies used for making stoneware and similar articles on which the letters are to appear sunk. The soft-metal letters are not well adapted for use on iron patterns, though they are occasionally employed, and, in such cases, are usually stuck on with beeswax, although it is an unsatisfactory adhesive. The metal letters are usually stuck to the wooden patterns by means of varnish.

53. Brass Letters.—Brass letters are made both with and without pins on their backs. The pins can be driven into wooden patterns or riveted to iron patterns, while those without pins may be secured to iron patterns by soldering or sweating. The process of sweating letters to patterns is as follows: The place where the letters are to go should be thoroughly cleaned and tinned; the back of the letters should also be tinned. The letters are then placed in position and heated either with a hot soldering point or by means of a blowpipe. This heat will melt the tinned surfaces together. Sweating on the letters makes a much neater job than riveting, and usually takes less time.

PATTERNMAKERS' TOOLS.

HAND TOOLS.

54. General Consideration of the Subject. — Every patternmaker is supposed to provide himself with certain tools, and, while many of them are of the same kind as those used by other wood workers, there are many others especially adapted for patternmaking. The patternmaker's kit of tools is probably more varied than that of any other wood worker, because of the endless variety of work he has to do.

Patternmakers themselves differ greatly in their choice of tools, as well as in their manner of work; hence, it is impossible to enumerate all the tools that may be used in patternmaking. Very often the patternmaker thinks that a certain way of executing a piece of work is best, but he may not be able to find a tool to suit his purpose, in which case he frequently improvises one himself or has it made.

55. Representative Kit of Patternmakers' Tools and Approximate Cost. — The following list of tools must not be considered the only ones that can be used for the purpose. In several cases, the makers' names have been given in connection with the tools mentioned, though in most instances there is more than one firm making each kind of tool. The costs may vary from time to time on account of the condition of the market or the grade of the tools, but such a set may ordinarily be obtained for about sixty dollars.

One tool box, 32 inches long, 18 inches wide, 16 inches deep, with trays; one 24-inch 10-point hand saw; one back saw; one 12-inch compass; one iron jack plane; one iron jointer plane; one iron smoothing plane; one iron block plane; five round planes, as follows, No. 1, $\frac{1}{4}$ inch width, and $\frac{1}{2}$ inch circle, No. 3, $\frac{1}{2}$ inch, and 1 inch, No. 5, $\frac{3}{4}$ inch, and $1\frac{1}{2}$ inches, No. 7, 1 inch, and 2 inches, No. 9, $1\frac{1}{4}$ inches, and $2\frac{1}{2}$ inches; three rabbet planes, $\frac{1}{2}$ inch, 1 inch, $1\frac{1}{2}$ inches; one 2-inch round face boxwood spoke shave; one No. 0

combination India oilstone; one each of No. 14 and No. 22 combination India oil slips; seven paring chisels with shanks of $\frac{1}{8}$-inch, $\frac{1}{4}$-inch, $\frac{3}{8}$-inch, $\frac{1}{2}$-inch, $\frac{3}{4}$-inch, 1-inch, $1\frac{1}{2}$-inch width; nine paring gouges, $\frac{1}{8}$ inch, $\frac{1}{4}$ inch, $\frac{3}{8}$ inch, $\frac{1}{2}$ inch, $\frac{3}{4}$ inch, 1 inch, $1\frac{1}{4}$ inches, $1\frac{1}{2}$ inches, 2 inches; one $2\frac{1}{2}$-inch sloid knife; one No. 19 Adis $\frac{3}{8}$-inch carving gouge; one No. 28 Adis $\frac{1}{2}$-inch carving gouge; one each of No. 31 $\frac{3}{8}$-inch, $\frac{1}{4}$-inch, $\frac{1}{8}$-inch carving gouge; one 12-ounce ball-faced claw hammer; one small long-peen hammer; one 8-inch try square; one carpenters' steel square; one 8-inch **T** bevel; one 12-inch Starrett's combination square and center head; one No. 65 Stanley's boxwood marking gauge; one folding draw knife, 8-inch blade; one 4-inch shingling hatchet; one set screwdrivers; one 2-foot folding rule, standard; one 2-foot rule, not folding, shrinkage; one 8-inch wing dividers; one excelsior pencil attachment; one 5-inch spring dividers; one 5-inch outside calipers; one 5-inch inside calipers; one ratchet brace; one set auger bits, $\frac{3}{16}$ inch to 1 inch; four twist drills with square shanks, $\frac{3}{32}$ inch, $\frac{1}{8}$ inch, $\frac{3}{16}$ inch, $\frac{1}{4}$ inch; one set adjustable leg trammel heads; one malleable-iron oil can; one extension bit with two cutters, to bore from $\frac{7}{8}$ inch to 3 inches; one double-cut countersink; one dozen assorted brad awls; two 3-inch malleable-iron **C** clamps; one $1\frac{1}{4}$-inch turning gouge; one $\frac{3}{4}$-inch turning gouge; one 1-inch turning chisel, ground on both sides; one $1\frac{3}{4}$-inch extra heavy turning chisel, ground on one side only; one each $1\frac{1}{4}$-inch right-hand and left-hand turning chisels, ground on one side only, and on the skew; one nail set; one 8-inch carpenters' pincers.

56. Care in Use of Tools.—This paper presupposes a knowledge of the uses of the ordinary wood-working tools on the part of the student; and, hence, this matter will not be taken up in detail, but a few hints concerning the care of tools may be of assistance.

All tools should be kept sharpened and in good order, if good work is to be expected of them. This fact cannot be too strongly impressed on all that use tools of any kind.

57. Wood-Working Tools.—Hand **wood-working tools,** such as chisels, gouges, etc., are usually ground on a grindstone, and finished on an oilstone. Care should be taken in grinding not to overheat the edges, so as to draw the temper, and in both the grinding and the sharpening on the oilstone, attention should be given to the angles at which the tools are sharpened so that these are uniform and suited to the material being worked.

58. Dogs and Driving Plates.—Where two pieces of wood are to be fastened together, **dogs** similar to that shown at *a*, Fig. 28, are frequently employed, which are driven into the end of the grain as indicated by the dotted

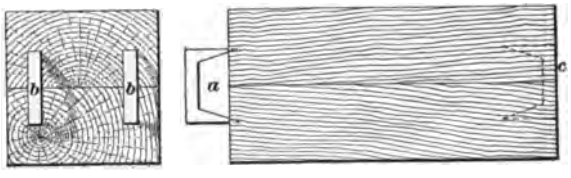


FIG. 28.

lines at *c*; *a* shows the general shape of the side of the dog, and *b* the back face. Such dogs as this should be kept on hand in a variety of sizes, and used in securing the parts of sectional patterns temporarily in place while they are being operated on.

59. When patterns are to be turned, metal plates are sometimes screwed to the pieces in place of dogs, and if the pieces are large and heavy, the centers on which the work is to be turned may be formed in the plate, as shown in Fig. 29, *a* being the plate screwed to the end of the pattern in such a manner as to join the

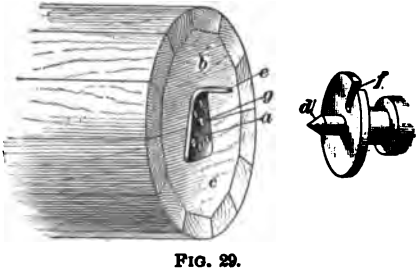


FIG. 29.

halves *b* and *c* together. In this case, a portion of the plate has been bent to form the driver *e*, which engages the slot *f* of the lathe face plate and serves as a driver for rotating the work, which is supported on a center *d*, which enters the hole *g* in the plate. These dogs and plates are usually not furnished by the patternmaker himself, but belong to the pattern shop.

SHOP TOOLS AND MACHINES.

60. General Consideration of Subject. — The variety and size of tools used in any pattern shop will depend on the amount of work being done and the character of the patterns being made. In the case of small pattern shops, comparatively few tools are required, while in large ones, and especially those doing heavy work, it is more economical to have a large number of machines. Only the machines necessary for patternmaking will be considered here. Those required for cutting down, ripping, and resawing stock, and preparing it for patternmaking will not be taken up in this connection, though in some cases large pattern shops are provided with such machinery.

SAWING MACHINES.

61. Universal Circular-Saw Bench.—All pattern shops should be provided with one or more circular saws. For general pattern work, the machine shown in Fig. 30 is probably as good as there is on the market. It consists of a heavy cast-iron frame, or base, *i*, which carries a stationary table *j* and a movable, or sliding, table *k*. There are two saws mounted on parallel arbors and so arranged that either of them can be brought above the table, and, also, so that the depth of cut or amount of saw exposed can be controlled. The ripping saw is shown at *a* and the cross-cutting saw at *b*. The hand wheel *c* on the front of the machine, Fig. 30,

controls the worm *h* and gear *g* shown in Fig. 31, and by this means serves to rotate the frame carrying the two saws and to bring either to the top. The portion of the table *k* is so arranged that it slides on guides, the weight being carried on rollers.

The sliding portion *k* is fitted with a cutting-off gauge *e*, which can be set at any angle, so as to cut the stock at right angles or to any desired bevel. The gauge is held on the table by means of taper pins and an adjusting clamp screw that passes through a quadrant, as shown in Fig. 30.

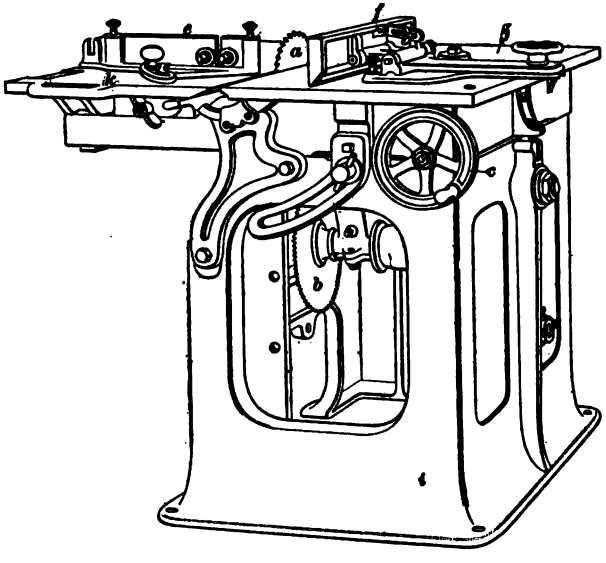


FIG. 30.

In Fig. 30, the slitting gauge, or fence, *f* is shown in place. This gauge is used for ripping, and is so arranged that it can be tilted to various angles. The portion of the table *k* can be locked in place, and the entire table tilted as shown in Fig. 31. In Fig. 31, the fence *f* has been placed on the movable portion of the table *k* and the table locked. This tilting of the table is very handy when sawing out staves for cylinders, columns, and similar patterns. The

table can be tilted to any desired angle up to 45°. One advantage of setting the gauge, or fence, as shown in Fig. 31, is that the weight of the stock tends to keep it against the

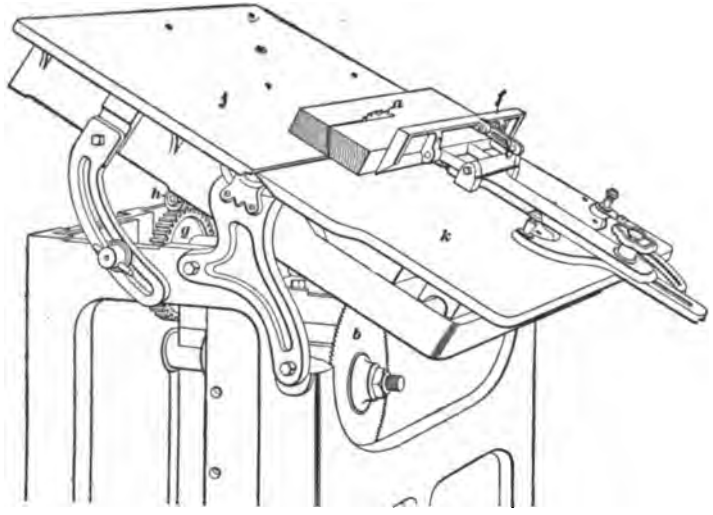


FIG. 31.

gauge. By means of this saw and its attachments, a patternmaker can save a great deal of time, as it will cut practically all angular forms.

62. Band Saws.—All machines employing circular saws are suitable only for angular work and for cutting along straight lines. For cutting irregular or curved lines, the **band saw,** as shown in Fig. 32, is very useful. In this machine, the stock to be cut is supported on the table *g*. The saw is in the form of a band and runs on the wheels *d* and *e*. One wheel *e* is driven by a belt and the pulley at *f*. In order to prevent the saw from crowding back and running off the carrying wheels *e* and *d*, a special guide and support *c* is provided. This guide is carried on an adjustable guide arm *a*.

The saw is held in place by means of two adjustable

blocks *b*, *b*, between which it runs, and the backward thrust is taken by the disk *h*, across one edge of which the saw travels. The disk *h* has a slow rotary motion caused by the friction of the saw traveling on it and this causes it to wear evenly. The upper wheel *d* is adjusted vertically so that band saws of slightly different length may be employed on

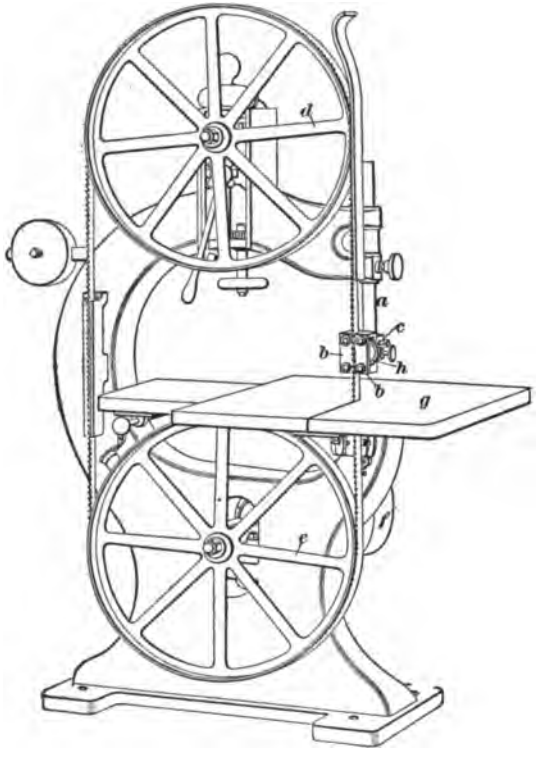


FIG. 32.

the machine. When in use, the guide *c* should always be set as close to the work as possible. It is well to box the space below the band-saw table, or, at least, to provide guards in front of the saw, in order to prevent pieces of material from getting between the spokes of the wheel and also the

workmen from accidentally coming in contact with this portion of the saw, and thus being injured.

63. Jig Saw.—Band saws are very useful for sawing most curved work, but when it becomes necessary to saw out the center of a piece, or to operate inside of a closed figure, the band saw cannot be used and some form of **jig saw** must be employed. Fig. 33 illustrates a machine of this character. The work is supported on the table *t* and operated on by the saw *c*. This saw is given a reciprocating motion by means of the crank disk *a* and pitman rod *b*. The upper end of the saw is carried by an adjustable guide *d*, which, like the guide of the band saw, should always be set close to the work. The guide *d* is adjusted by means of the hand wheel *e*. The upper end of the saw is attached to a bar or a strap carried by springs *g*, which serve to keep the saw taut.

FIG. 33.

The framework carrying the guide and springs is supported by a brace *h*, hanging from the ceiling. This brace is steadied by three rods *f*, which can be adjusted by means of turnbuckles, as shown. The jig saw is not as convenient as the band saw and will not work as fast, because it only cuts during the down

stroke. In other words, it only saws half of the time while the band saw is cutting continuously. When working inside of closed figures, the jig saw is detached from the straining frame and passed through a hole in the work, after which the straining frame is again attached and the work continued.

SURFACING MACHINES.

64. Rotary Planer.—Fig. 34 illustrates a typical **planing,** or **surfacing, machine** that is well adapted for work in a pattern shop. The machine shown is carried on a heavy cast-iron base *g* and is provided with a two-part adjusting table, the parts *a* and *d* being separately adjusted by means of the hand wheels and screws shown at *e* and *f*. The portion *a* is so adjusted as to receive the work after it is cut; the table *d* should be adjusted lower, so that the

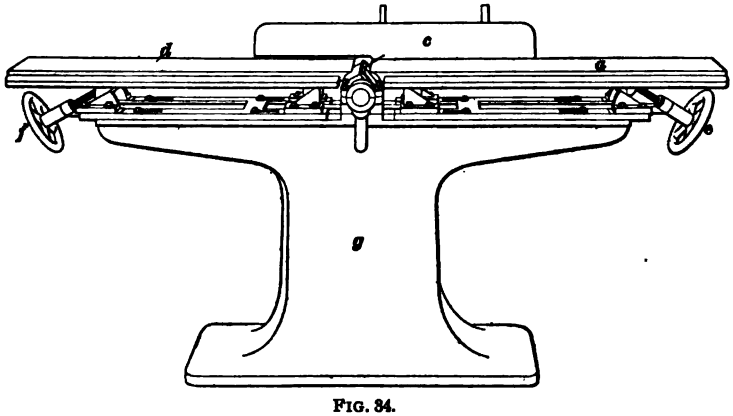


FIG. 34.

difference in elevation between the two tables represents the depth of cut being taken. The work is held by hand against the guide *c*. Various special attachments and guides may be used in connection with these planers, and they are also handy for truing up and smoothing work. Among the operations that may be easily performed on this style of machine are chamfering, beveling surfaces, and, to a certain extent, taking the piece out of wind, though, owing

to the fact that the work is fed over the table by hand, it is impossible to entirely remove wind in this style of machine.

65. Daniel's Planer.—This style of machine is used almost entirely for taking work out of wind, but differs from the one illustrated in Fig. 34 in that it is provided with a movable table similar to that of an iron-planing machine. The piece of wood to be operated on is secured to this table by suitable dogs or clamps and the work is then passed under the rotating knives. These knives are usually rotated in a horizontal plane on the end of a vertical axis. A planer of this kind will take wind out of timber perfectly, on account of the fact that the timber is rigidly held in place while being operated on, but the **Daniel's planer** is not suitable for work on very thin stock, nor will it answer for the large variety of work covered by the form shown in Fig. 34.

LATHES.

66. Face-Plate Lathes.—For turning large patterns, **face-plate lathes** are employed, as shown in Fig. 35. In this form, the lathe is supported on a heavy base *a* and is provided with a short rigid spindle running in bearings *b*, *b*. Power is furnished by a belt running on the cone pulley *c*. On the end of the spindle is placed an iron face plate *d* and to this are screwed boards that are then turned off to form a wooden face plate of large diameter. The

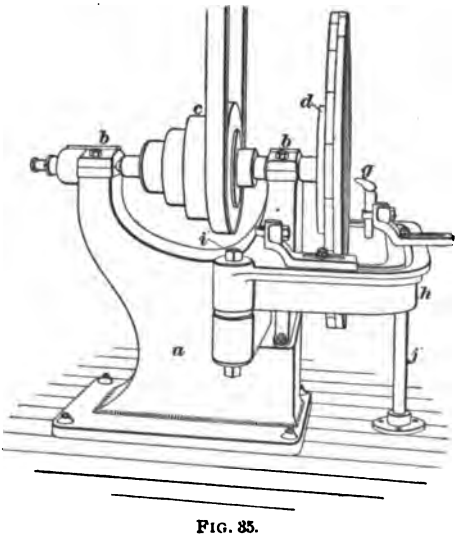


FIG. 35.

work to be turned is bolted or screwed to this large wooden face plate. Turning tools are used over the hand rest *g*, which, in this case, is carried by a support *h*, which is pivoted at *i* so that it can be swung away from the front of the lathe. This bridge, or support, that carries the rest is provided with a leg *j*, which can be adjusted directly beneath the rest *g*. When turning very large work, or work that projects some distance from the face plate, it is frequently necessary to swing the arm *h* out of the way, and to arrange a rest on a temporary wooden horse. Every pattern shop, where work of any size is done, should be provided with one or more of these face-plate lathes.

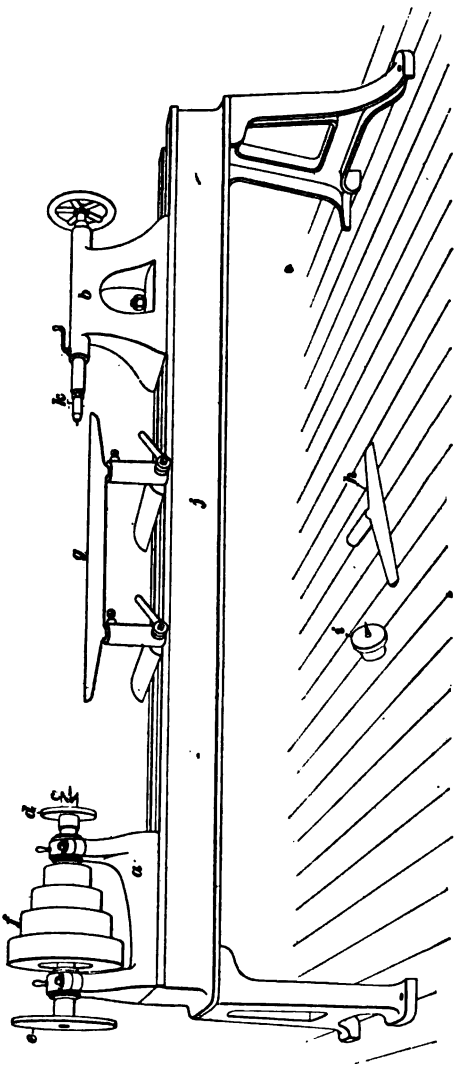


FIG. 36.

67. Large Combination Lathe.—Fig. 36 illustrates a very handy lathe for use in the pattern shop. The bed,

or shears, *j* is supported on suitable cast-iron legs, as shown. On these shears are placed the headstock *a* and the tailstock *b*, also the movable rests. As shown in the illustration, the long rest *g* is in place, being supported at two points. When short work is to be turned, only one of the supports is employed and the rest shown on the floor at *h* may be used.

68. Long and slender work is turned between centers of the lathe, *c* being the live, or driving, center and *k* the dead center. Small work may be screwed, or otherwise secured, to the small cast-iron face plate *d*. Sometimes the small face plate *d* is replaced by the casting shown on the floor at *i*. This casting has a threaded spike, or screw, in its center so that small pieces of work may be screwed on it, thus doing away with the use of other screws or fastenings.

When work that cannot be swung over the shears of the lathe is to be turned, it may be secured to the face plate *e*, which is placed on the other end of the spindle and so arranged that it overhangs one end of the lathe. When this face plate is used, it is necessary to rig up a temporary rest on wooden blocking to carry the regular iron rest. The shears of such a lathe as this are usually about 18 feet long and it is arranged to turn about 30 inches in diameter over the shears. In some cases, the shears *j* are made of wood.

69. Small Wood-Turning Lathe. — All pattern shops, and especially those handling small work, should be provided with at least one small lathe capable of swinging from 12 to 16 inches over the bed. This small lathe is in general appearance like that shown in Fig. 36, but is not provided with the overhung face plate *e*, all the work being done between the centers. Sometimes, even in special classes of work, small bench lathes are used in patternmaking, but, as a rule, one having from a 12-inch to 16-inch swing is as small as would be required.

MISCELLANEOUS TOOLS AND APPLIANCES.

TRIMMERS.

70. Bench Trimmer.—While adjustable saws similar to those shown in Figs. 30 and 31 will cut wood to any angle, they do not make good surfaces for gluing, especially on the end grain. Owing to the fact that it is difficult

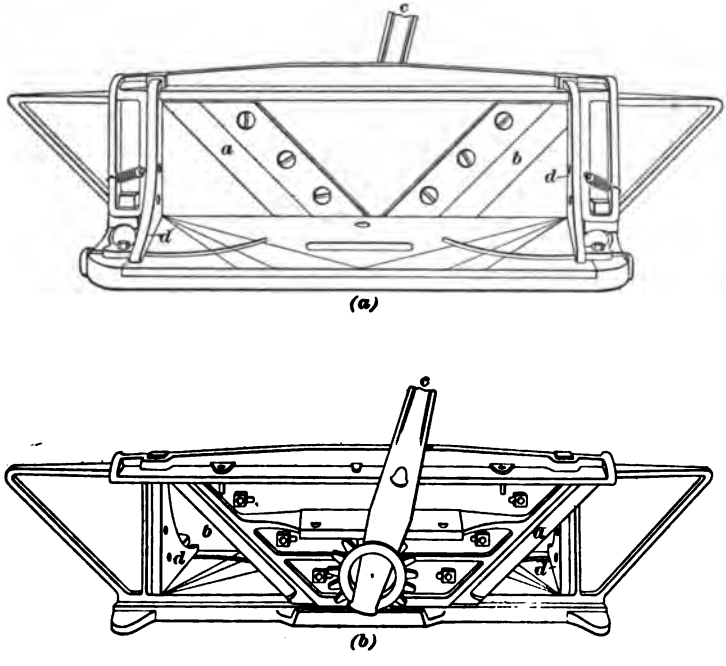


FIG. 37.

to produce these surfaces with hand tools, **trimming machines** have been placed on the market. Fig. 37 (*a*) illustrates a front view and Fig. 37 (*b*) a back view of one of these trimmers intended for use upon a bench.

The stock to be trimmed is placed against one of the adjustable wing guides, as shown at *d*, and one or the other

of the knives *a*, *b* is employed to trim the end of the piece, the lever *c* being used for operating the knives. The bed of this machine has various angles marked on it, and the adjustable wings *d* may be set at any desired angle. This enables the trimmer to finish the ends of pieces to form segments for figures having any desired number of pieces in the circle. These bench trimmers are generally a part of the shop equipment, but are sometimes owned by individual patternmakers and are kept on their own benches.

71. Large Trimming Machine. — Fig. 38 shows front and back views of a large trimming machine similar in action to the bench trimmer. This machine has a much larger capacity and is mounted on a rigid base. Instead

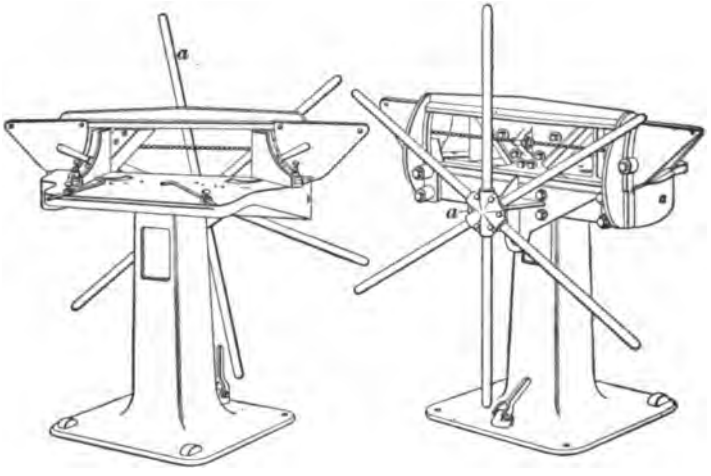


FIG. 38.

of operating the knives by means of a lever, they are operated by the capstan wheel shown at *a*. As in the smaller machine, the bed is provided with adjustable guides, so that any desired angle may be cut. Large machines of this class are a portion of the regular equipment of the shop and are supplied by the owners.

GRINDSTONES.

72. All pattern shops should be provided with **grindstones** for the use of the men in sharpening both the hand tools and the tools for the machines. The grindstones for use in the pattern shop should be well mounted, and many men prefer using a wooden rest for supporting the tool while grinding. Ordinarily, for wood-working tools, the grindstone is run at a speed of about 600 feet per minute. Others run the stone at such a speed that the water will just remain upon it without being thrown about the shop. Grindstones always cut better when they are used wet, but they should never be left standing in water.

CLAMPS.

73. All pattern shops should be provided with plenty of **clamps** for holding work while the glue is hardening. The form of wooden parallel clamp shown in Fig. 39 is the most serviceable, and several dozen of these should be on hand. Metal **C** clamps are also used to some extent. It is also desirable to have special clamps for securing large pieces. These are frequently made by placing one fixed and one adjustable jaw on a piece of timber 5 or 6 feet long, the adjustable jaw being so arranged that it can be moved 2 or 3 inches at a time and secured in the desired positions by means of a pin or notches. The finer adjustments are obtained by means of a screw carried by one of the jaws.

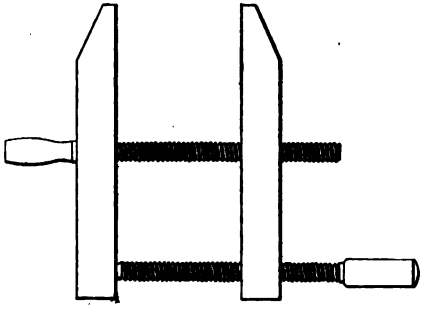


FIG. 39.

WORK BENCH.

74. General Consideration of Bench. — Probably one of the most suitable benches for use in the pattern shop is a regular cabinetmaker's bench, such as is shown in

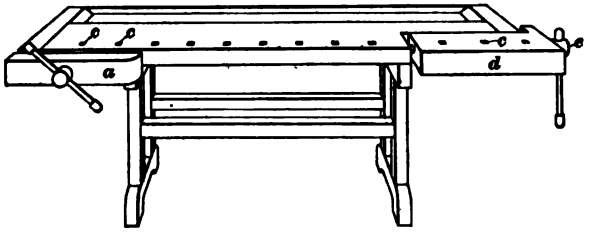


FIG. 40.

Fig. 40. This bench is provided with two vises, one at *a* and one at *d*, and also with a series of holes, as *c*, *c*, to receive movable stop-pins. Fig. 41 illustrates a common form of stop-pin for use in such holes. The pin is held at any desired height by means of the spring *x* and the work is placed against the face *b*. It will be noticed that the vise *d*, Fig. 40, is really a portion of the bench, so mounted that it can be moved by means of the screw *e*. This portion of the bench carries several of the stop-pin holes *c*. By using one stop-pin in one of the holes in *d* and another in the bench, it is possible to clamp long pieces of work flat upon the surface of the bench.

FIG. 41.

75. Adjustable Bench Stops.—While the form of bench stop shown in Fig. 41 is very useful, it is well to have an **adjustable bench stop** of a form similar to those shown in Fig. 42. These are intended for holding the end of work steady while it is being planed. The one shown in Fig. 42 (*a*) has a cylindrical bar, or stem, *b*, which carries the stop-head *a*. The stop can be secured at any height by means of the screw *c*, the head of which projects through the front of the bench. This form is useful on account of the fact that by loosening the screw *c*, the stop can be turned so as to engage the end of work that is not

sawed off square. Fig. 42 (*b*) shows another form of bench stop in which the head *a* is mounted on a square bar *b*.

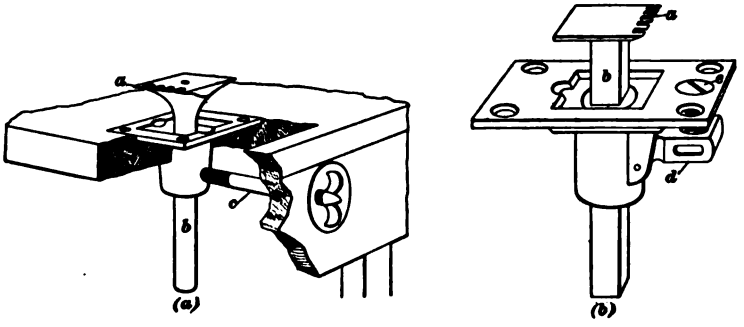


FIG. 42.

This bar can be clamped in place by means of the clamping lever *d*, which is operated by the screw *e*. Usually, one such stop is placed at the left-hand end of the bench.

76. Vises.—For general patternmaking, the form of **vise** shown at *a*, Fig. 40, is frequently replaced by a quick-closing vise. Fig. 43 illustrates a vise belonging to this class. The jaws are controlled by the lever *a*, which operates a cam *b*. This cam controls a block *c* working against the toothed rack *d*. When this lever is brought to one position, the block *c* drops out of contact with the rack and the jaw can be moved to approximately any desired position. The first action that results on turning the lever is the raising of block *c* into contact with the rack *d*, and after it is in contact, the cam draws the movable jaw *e* toward the fixed jaw *f*. Such a vise as this can be very quickly adjusted and is extremely useful for many classes of work. Similar vises using screws are manufactured, and are so arranged that the nuts can be temporarily separated for quick adjustment.

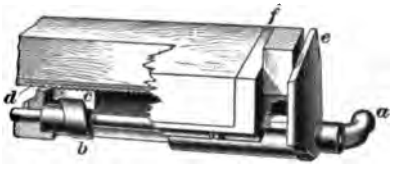


FIG. 43.

77. Bench Hook.—One very useful accessory to the work bench is the **bench hook** shown in Fig. 44. This really forms a movable stop that can be used at right angles to the front face of the bench. When it is desired to saw off a piece of stock, the bench hook is placed on the bench, one shoulder being set against the edge of the bench while the upper shoulder serves as a stop for the stock while sawing.

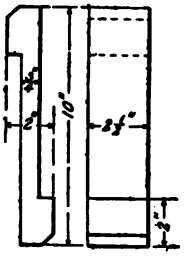


FIG. 44.

PATTERNMAKING.

(PART 2.)

ALLOWANCES NECESSARY IN PATTERNMAKING.

1. General Consideration of Allowances. — In practice, it has been found that a casting obtained from a pattern is rarely, if ever, of exactly the same size and shape as the pattern itself, and, to overcome this difficulty, certain allowances must be made. In order to understand the conditions that exist and to make these allowances properly, it is necessary to study the causes of the different variations. The principal allowances necessary are for *draft*, *shrinkage*, *finish*, and *shake*. Each one of these will be taken up separately.

DRAFT.

2. The pattern is usually given a slight taper so that it may be more easily withdrawn from the mold. This taper is called the **draft.** The surface from which the draft runs is called the *face* of the pattern, and is usually the uppermost surface of the mold when the pattern is drawn. Fig. 1 illustrates the manner in which the allowance for draft is made. The shape of the required casting is indicated by the dotted lines. It will be noticed that the draft has been given by increasing certain dimensions of the pattern. For instance, the diameter of the flange *c d* has been increased at

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the face to *a b* and the diameter of the hole *g h* has been decreased at the face to *e f*, thus increasing the thickness of the pattern. No unvarying rule as to the amount of draft can be given. On comparatively small work, a taper of $\frac{1}{16}$ inch per foot represents, approximately, an average amount, but in some cases very much less is employed, while in other cases a greater amount is given. Some patterns are of such form that they do not require an allowance for draft, because of the fact that none of the surfaces are at right angles to the face.

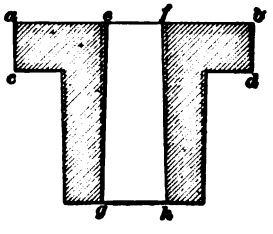

FIG. 1.

SHRINKAGE.

3. General Consideration of Shrinkage.—An iron casting is always smaller than the mold in which it is made, and this is true of castings made from any of the metals in common use. This difference in size is due to the **shrinkage** of the metal when cooling. The amount of shrinkage varies with the shape and size of the casting and with the kind of metal employed. Brass, for instance, will shrink more than iron; and, again, iron that is very hot will shrink more than iron that is comparatively cool when poured.

4. Allowances for Shrinkage.—The shape and size of a casting have so much to do with the amount of shrinkage that an iron which will shrink $\frac{1}{8}$ inch to the foot in light work may only shrink $\frac{1}{10}$ inch or less in the case of heavy work. For instance, when casting large cylindrical or box-shaped iron castings, an allowance of $\frac{1}{10}$ inch to the foot in length and from $\frac{1}{16}$ to $\frac{1}{20}$ inch to the foot in diameter is usually a sufficient allowance for shrinkage. The reason for the difference in the allowance for length and diameter is due to the fact that the castings are practically unrestricted in their length and are comparatively free to shrink in this

direction, while in the diameter the shrinkage is restricted by the cores and internal parts of the mold.

The usual allowances that patternmakers make for shrinkage for ordinary purposes are as follows: iron, $\frac{1}{8}$ inch per foot; common brass, $\frac{3}{16}$ inch per foot; yellow brass, $\frac{7}{32}$ inch per foot; aluminum, $\frac{1}{4}$ inch per foot; steel castings, from $\frac{1}{8}$ to $\frac{1}{4}$ inch per foot, depending on the kind of casting and the temperature at which it is to be poured.

FINISH.

5. Definition.—When the surface of the casting is to be cut away or finished, an allowance equal to the amount removed is added to the pattern and is called an allowance for **finish.**

6. Allowance Necessary for Finish.—The allowance made for finish must always be sufficient so that all the scale will be removed and clean metal exposed. For iron, an allowance of from $\frac{1}{16}$ to $\frac{1}{8}$ inch is sufficient in the case of small work, but as the size of the casting increases, its irregularities and the total amount of shrinkage increase, and a greater allowance for finish must be made. In the case of heavy engine beds and similar large castings, an allowance of from $\frac{1}{4}$ to 1 inch is frequently made. Steel castings are usually very rough, especially when large, and they also become more or less distorted in casting and annealing. On this account, an extra allowance is made for finish. Each individual shop must determine its own system of allowances for finish, as it is dependent in part on the manner in which the work is machined and the molding done.

SHAKE.

7. Conditions Under Which the Allowance Becomes Necessary.—The molder usually loosens the pattern in the mold by rapping before withdrawing it. As this tends to increase the size of the mold, it may become

necessary to make an allowance for **shake** in some cases, especially when dealing with small castings, or the small details of large castings.

If small castings are intended to fit together without finish, as shown in Fig. 2, the dimension *a* on the piece *c* is increased by shake, while the space *a* on the piece *b* is reduced, and, as a consequence, the two pieces will not fit together; hence the patterns should be made with an allowance for shake, the dotted lines indicating such allowance. In this case, the two patterns would go together loosely, but the two castings would probably go together tightly. It is very rare that the attempt is made to fit castings together without some finish, but very frequently it is necessary to make an allowance for shake. It is impossible to give any definite amount as the proper allowance for shake, as this must be determined by experiment in almost every case. Usually, an allowance for shake is only made on small patterns, and it is not often required in cases where the dimensions of the pattern exceed 4 inches. On small pieces, shake and shrinkage tend to neutralize each other, and in many cases they are supposed to do so between the limits of 4 and 6 inches. On dimensions of over 6 inches, an allowance is usually made for shrinkage.

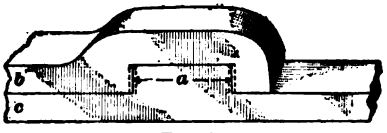

FIG. 2.

WARP.

8. Conditions Governing Warp. — Some castings will become distorted in the mold when cooling, owing to their varying thickness or to one surface being exposed more than another so that it cools more rapidly. For this reason, it is frequently necessary for the patternmaker to make some allowance for **warp** by changing the shape of the pattern. The amount of allowance necessary must be determined by trial in almost every case, but there are some general rules or laws that govern such cases, and by

studying them and exercising a little care in molding, these difficulties may frequently be overcome. If a casting of the form shown in Fig. 3 is desired, it will be noticed that the web *a* is thin compared with the upper portion of the casting *b*. This web would cool first and thus determine the length of the lower portion of the casting. The portion *b* would cool more slowly and would contract somewhat after the web *a* had become permanently set.

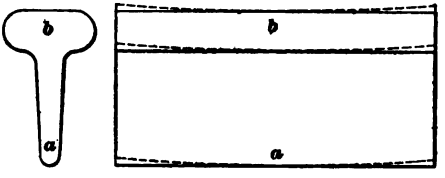

FIG. 3.

The shortening of the upper face of the casting would tend to warp it as indicated, somewhat exaggerated, by the dotted lines. In other words, the portion that contains the largest body of metal cools last and tends to become the shortest. In order to make this casting straight, it is necessary to make the upper face of the pattern convex or to cause the upper face to cool more rapidly than the lower portion. The latter may be accomplished in molding by bedding the web *a* deep in the sand and having only a thin layer of sand on top of the portion *b* so that the heat will radiate and escape from it rapidly. Frequently, molders uncover or partially uncover large masses or heavy irregular parts of castings so as to cause them to cool more rapidly and thus reduce the strains caused by irregular cooling. When casting plates that are strengthened by means of ribs, care should be taken to make the ribs approximately the same thickness as the plate, as, otherwise, they will have a decided tendency to warp the casting.

MARKING AND RECORDING PATTERNS.

9. Necessity of a System.—Where a large number of patterns must be stored and taken care of, it is important to have some system by means of which any given pattern can be immediately located and by means of which castings can be ordered from any given pattern. The system in

most common use is to fix some mark or symbol upon each pattern and then make a record of this symbol. It would be impossible to give examples of all the different systems employed for marking and recording patterns, but the following general description can be applied in most cases, or a modification of it can be worked out for any given case. The advantages of having a system are as follows: The marks facilitate the ordering of castings and help to prevent confusion in the foundry and the mixing of patterns. When the order for a casting is written out (as it always should be), the mark corresponding to that on the pattern is put on the order so that the molder and the pattern-maker cannot misunderstand each other by naming parts differently.

10. Marking Patterns.—To mark a pattern, a letter and number may be fixed upon each pattern so that they will appear on the casting. The letter is to designate the class of machinery, or it may be used for a certain machine. The number is to designate one part of the machine from another.

In the case of large manufacturers that have patterns for a number of different classes of machines, and often a number of different sizes of machines in each class, the question may arise as to what should be done when the alphabet is exhausted. In this case, two letters can be used to designate a machine or class, commencing with *AA*, *AB*, *AC*, and so on through the alphabet again; then begin with *BA*, *BB*, *BC*, etc. Thus it will be seen that it is possible to have a large combination of distinct and separate classes without confusion. The mark placed upon each pattern should also be entered on the drawings. This is frequently neglected, but where it is done, it greatly facilitates the work in the machine shop.

In the case of patterns having core boxes or loose pieces, each piece or core box should receive the mark, as this will enable the foundry man to keep the pieces together and to avoid mistakes.

SPECIMEN ENTRY FOR PATTERN RECORD BOOK.

18-INCH AND 20-INCH CORLISS ENGINES.

Pattern Mark.	Name of Part.	Castings Wanted.	Weight.	Pattern At	Remarks.
A 1	Engine frame, 18"×36"	1	3,555	2	
A 1	Engine frame, 18"×42"	1	3,905		This pattern is constructed so that it can easily be changed to different strokes and sizes.
A 1	Engine frame, 18"×48"	1			
A 1	Engine frame, 20"×36"	1			
A 1	Engine frame, 20"×42"	1			
A 1	Engine frame, 20"×48"	1			
A 2	Main pillow-block	1	2,015	3	
A 3	Cap for block	1	475		
A 4	Oil cover	1	10		
A 5	Corliss cylinder, 18"×36"	1	3,790	2	
A 5	Corliss cylinder, 18"×42"	1	4,290		
A 5	Corliss cylinder, 18"×48"	1			Patterns are arranged on the telescopic principle.
A 6	Corliss cylinder, 20"×36"	1	4,125		
A 6	Corliss cylinder, 20"×42"	1	4,280		
A 6	Corliss cylinder, 20"×48"				
A 7	Frame foot	1		1	
A 8	Cylinder feet (20" cylinder)	2			
A 8	Cylinder feet (18" cylinder)	2			
A 9	Crank, 36" stroke	1			
A 10	Crank, 42" stroke	1			
	Brass.				
A 70	Key heads	12			
A 71	Knock-off latches	2			Strong bronze.
A 72	Connecting-rod box	1			Crank end.
A 73	Connecting-rod box	1			Crosshead end.
A 74	Bushing for piston rod	1			
A 75	Bonnet bushings	4			
A 76	Eccentric strap shims	2			
	Steel Castings.				
A 100	Crosshead nut	1		4	Nov. 3, 1892.
A 101	Cheek pieces for pattern block	2		4	Nov. 3, 1892.

INDEX OF FIRMS TO WHOM PATTERNS ARE SENT.

1 Eddy Foundry Co., Chicago, Iron Foundry.
2 Chicago Foundry Co., Chicago, Iron Foundry.
3 Bouton Foundry Co., Chicago, Iron Foundry.
4 Pittsburg Steel Casting Co., Pittsburg, Steel Foundry.

11. Recording Patterns.—The accompanying sample entry, taken from a pattern-recording book, will serve to illustrate the manner in which this work may be carried out.

12. The column marked "Pattern At" will be found very useful when patterns are sent to outside foundries, as it will enable the patternmaker to locate all his patterns accurately. In connection with this column, an index is made showing the names of firms to whom patterns have been sent. Each firm is given a number, as shown. When a pattern is sent out, the number corresponding to the firm to whom it has been sent is marked with a lead pencil in the number column and opposite the pattern that is sent out. When it is returned, the lead-pencil mark is erased, showing that it has been returned and restored to its place.

It often appears that in a set of patterns for a certain machine, there are some parts that can be used on other machines. In such cases, entries should be made in the schedule of each machine, stating that these pieces can be used and giving the letter and number upon each piece.

13. Miscellaneous Patterns. — There is always a large number of miscellaneous patterns that cannot well be classified, yet many of them are frequently recorded and should be marked so that they can easily be found. These may be given a symbol and entered under the head of miscellaneous.

14. Rough Patterns.—There are always some rough patterns made that are wanted simply for a single casting and are frequently of the skeleton type. These patterns are usually not recorded and it is generally best to destroy them as soon as they have served their purpose.

15. General Remarks on Recording.—As a rule, the billing and shipping clerks that handle patterns are not familiar with the names of the parts of the machines; hence, matters are greatly simplified by having these parts recorded by letter and number, and by adopting such a

system it is possible even for a stranger to find any desired pattern, providing the shelves or bins where the patterns are stored are marked with the letter corresponding to the class belonging there. The system described is intended simply as a suggestion in order to show how the work may be carried out, but every pattern shop should have some definite system of its own and a definite order for storing and keeping the patterns. Sometimes shops adopt a system of painting all outside faces of patterns a different color from the faces that come in contact with other portions of the pattern, so that the molder can tell at a glance whether some piece of the pattern is lacking or not.

MAKING PATTERNS.

SMALL RECTANGULAR PATTERNS AND CORE BOXES.

16. Patterns for Solid Castings.—Patterns of this kind are usually made solid by first sawing the stock to approximately the required size and then finishing it with a plane or such other tools as may be most convenient. In getting out the stock from which to make patterns, it is necessary to take into account not only the allowances for draft, shrinkage, shake, and finish, but also to allow sufficient material for the finishing of the pattern with the planes, chisels, or other tools employed.

17. When a pattern is thin and flat, as shown in Fig. 4, the allowance for draft may be disregarded, on account of the fact that the rapping will be all that is necessary to free the pattern from the sand so that it can be removed from the mold, and, in the case of small patterns, that is, up to 6 inches, the rapping will also enlarge the mold sufficiently to compensate for the shrinkage of the casting due to cooling.

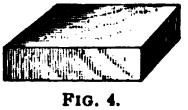

FIG. 4.

18. When the depth of the pattern is comparatively great, as in the case shown in Fig. 5, an allowance for draft must be made. The face *a* of the pattern is larger than the required size of the casting by the amount necessary for draft. The opposite end *b* of the pattern is made of the required size, the dotted lines indicating the amount that has been added to provide for draft. In the case of large solid castings, the patterns are sometimes made hollow like wooden boxes, so as to make them lighter for the molder to handle and also to reduce the amount of timber necessary in the pattern.

FIG. 5.

19. Patterns for Hollow Castings. — When it is required that there shall be openings in or through the casting, the pattern is made to leave its own core when possible. Fig. 6 illustrates a cross-section of a mold containing a pattern. At *a*, the pattern leaves a mass of sand forming a core that will make a hole entirely through the casting, while at *b* simply a small ridge of sand is left as a core to form a depression in the metal. Both of these cores are left by the pattern. In such cases as this, the inside of the opening for forming the core and the outside of the pattern are both given a slight taper from the face, for draft.

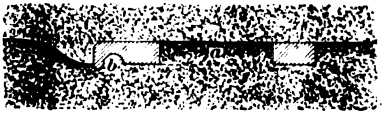

FIG. 6.

20. When the core becomes long so that it is impossible to draw the pattern from around it, or when the core is of such a shape that a pattern cannot be drawn, it becomes necessary to use a separate core. Short square cores may be formed in a simple core box like the one shown at Fig. 7 (*a*) and short cylindrical cores in a box similar to the one shown at Fig. 7 (*b*). In this case, the opening for the core is simply an opening bored through a block of

wood that has been sawed apart to facilitate the removing of the core. In sawing, the parting line has been made

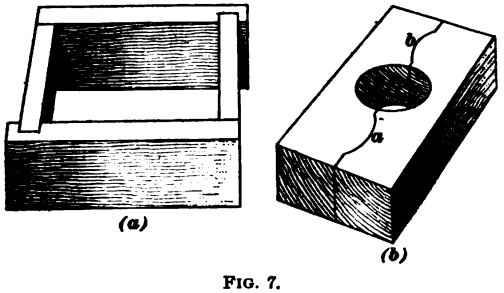

FIG. 7.

irregular, as shown at *a* and *b*, these curves serving to properly locate the parts of the core box. Other devices for accomplishing this same thing will be illustrated later.

PATTERN TURNING.

21. Distinctive Features of Pattern Turning.— The operation of pattern turning is carried on in a different manner from the ordinary work of the wood turner. Ordinarily, the patternmaker does not use a tool ground on both sides and held sidewise for finishing as does the wood turner, but employs a thick chisel ground on one side only, with which he scrapes the work by firmly holding the chisel flatwise on the rest. Patternmakers turn in this way because the work must be approximately round and of exact size, the finish being of secondary importance, and also because it is possible to produce the finish later by other means. In the case of a regular wood turner, the work is rarely required turned to exact dimensions, but a smooth finish is usually of great importance.

The patternmaker usually turns small core prints and similar small work just as the ordinary wood turner would, with a chisel ground on the skew and on both sides. In the case of heavy work, especially when turning built-up patterns, the work is frequently firmly secured in a lathe, and

a sliding rest, similar to that employed in the metal-working lathes, placed before it, the turning being done by means of tools held in the rest.

EXAMPLE OF SIMPLE TURNED PATTERNS.

22. Pattern for Solid Roller.—The pattern shown in Fig. 8 may be taken as a fair representative of this class. The kind of pattern made to produce this roller will depend largely on the number of castings required and the facilities at hand. When but a few castings are wanted, a pattern will be turned out of one piece having the same shape as the casting. This simplification of the work of the pattern-maker throws additional labor on the molder on account of the fact that it necessitates his cutting down the parting line of the mold, as shown in Fig. 9. The pattern is shown at *r*, and it will be noticed that the molder has been forced to cut away the sand along the lines *a b* and *c d* so as to

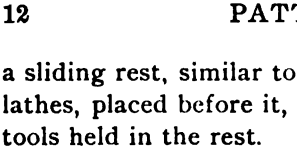

FIG. 8.

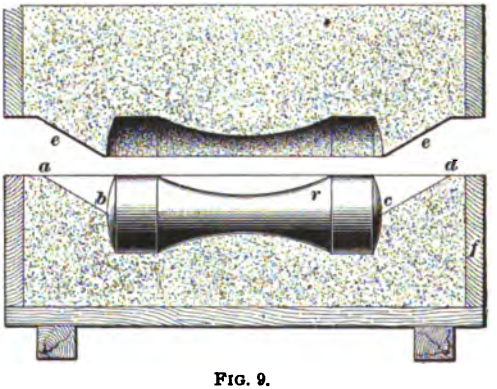

FIG. 9.

enable him to draw the pattern from the mold. This leaves the lower portion of the mold comparatively simple, but the cope or upper portion will have a body of sand hanging from it as shown at *e*, and this is objectionable in most work.

23. If a great number of castings is wanted, the patternmaker may still make a solid pattern and, in addition, make what is called an *odd side* or *match*. This is illustrated in Figs. 10 and 11. In Fig. 10, the pattern *a* is shown embedded half its depth in plaster or oil sand. The odd side is made in a box *c*, which must be of the same size

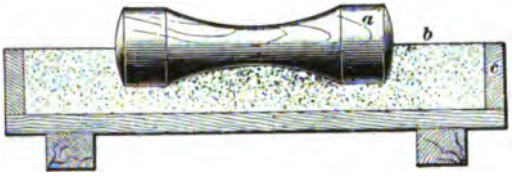

FIG. 10.

as the mold. If it is made of plaster, it is allowed to harden, and if made of oil sand, it is dried until the material has become firm. The plaster or sand is usually made to adhere to the box *c* by means of nails driven on the inside of the box. The method of using the odd side is shown in Fig. 11, in which *a* is the pattern, *b* is the sand or plaster of

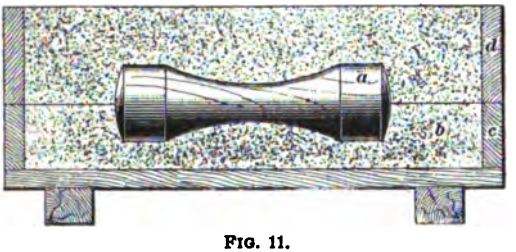

FIG. 11.

the odd side, *c* is the box containing it, and *d* is the nowel of the flask. This is placed upon the box *c* and sand rammed in as shown, after which the whole is turned over, the odd side removed, and molding proceeds as usual. If it is so desired, several solid patterns may be made and an odd side provided that will accommodate all of them.

24. Jointed Roller Pattern.—When there is only a moderate number of castings required, the patternmaker usually provides a jointed pattern. This is also frequently

done on account of the fact that odd sides or matches are large and awkward and inconvenient to store, also the odd side, or match, can only be used with a flask of the same size as the box containing it, while, with a jointed pattern, any form of flask of sufficient size may be employed. In a jointed pattern, the molding is facilitated by making the pattern in halves. To make a pattern for the roller

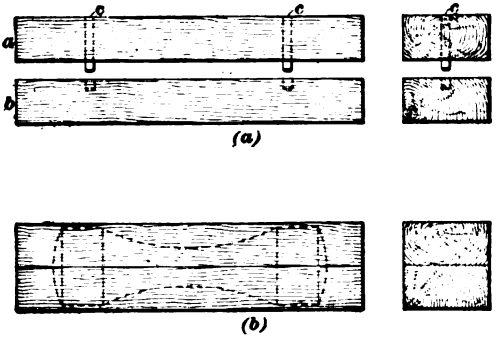

FIG. 12.

illustrated in Fig. 8, two pieces of wood should be taken as shown in Fig. 12 (*a*). These pieces are sawed from a board or plank and are larger than the required pattern so as to allow for finishing the pattern. Fig. 12 (*b*) shows the two pieces face to face and the outline of the required pattern drawn upon them, thus illustrating the allowances that are ordinarily made.

25. The pieces should next be doweled together. If wooden dowels are employed, they may be put in place by clamping one piece on top of the other and boring through the first and partly through the second, as shown by the dotted lines at *c*, *c*, Fig. 12 (*a*). If it is desired to keep the outside surface of the pattern unbroken, the holes may be located by laying two small wire nails between the pieces and then tapping the other piece with a hammer or mallet. The heads of the nails will make impressions in each piece,

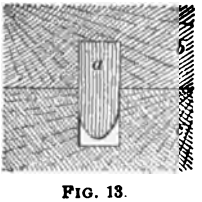

FIG. 13.

which will indicate the centers of the holes to be bored. Fig. 13 illustrates a dowel that has been put in in this manner, *a* being the dowel, which is glued to the portion of the pattern *b* and fits into the hole in *c*. The pins should not be placed at equal distances from the ends of the pattern, but one should be nearer the center than the other, so that the molder can put the pattern together without hesitation. The pins must be put in and glued before the turning of the pattern is done.

26. If brass pins and plates are employed, the plates with the dowel-holes are inserted into one half of the pattern first. The pin plates are then put on top of the inserted ones and the other half of the pattern set on top of it. A tap with a mallet will cause the pieces to make impressions on this upper piece of the pattern, and will thus locate the holes that must be bored.

27. The two pieces of the pattern must next be fastened together in such a way that they can be turned as one piece. This can be done by inserting screws near the ends, as shown in Fig. 14, or by inserting dogs, as shown in Fig. 28, *Patternmaking*, Part 1.

Another method that is commonly employed for holding the pieces together while being turned, is to glue a piece of paper on one of the pieces and then glue the other piece on to this paper. Sometimes the entire surface of the pattern is not covered with the paper, but strips are simply glued between the ends. If pieces have been joined by gluing paper between them, after the pattern is finished, they may be separated by inserting a knife blade or chisel between them, leaving one-half of the paper on each piece. When patterns are secured by glue and paper, care must be taken in turning to avoid accidents because of the tendency of

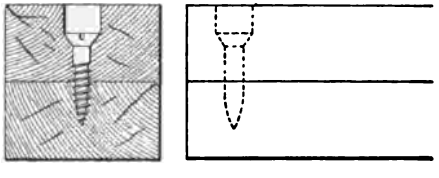

FIG. 14.

the glued pieces to fly apart, owing to the great speed at which they are revolving in the lathe. After the pieces are secured together, the pattern is turned to the form shown in Fig. 8; it is then removed from the lathe and the parts separated. The ends should never be turned entirely off in the lathe, but should be turned to a thin neck, which is subsequently sawed off and finished with a knife or chisel.

LARGE CYLINDRICAL PATTERNS.

28. Built-Up Patterns.—Large cylindrical patterns of the class illustrated in Fig. 15 are generally built up of staves that are carefully joined and fastened to supports or guides. The general method of joining staves and attaching them to supports is shown in Fig. 16, in which *a* and *b* are the supports and *d*, *d* the staves. In the illustration, the board *c* has been let into the supports *a* and *b* in order to give additional stiffness to the pattern while it is being built up. This is not always done, and sometimes when it is done, the board *c* is allowed to stop at the end supports *a* and *b*. In the case of long patterns, it becomes necessary to use more than two supports for the staves.

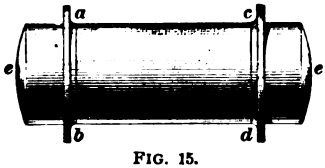

FIG. 15.

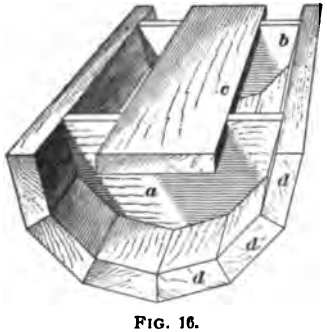

FIG. 16.

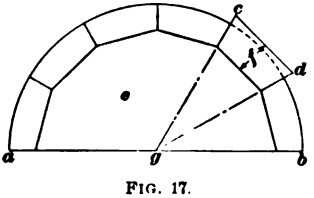

FIG. 17.

29. Before proceeding with the pattern, a drawing should be made as shown in Fig. 17. This drawing is made on stiff paper or on a thin piece of wood. The half circle for the outside of the pattern is drawn and on this the staves are laid off,

enough stock being left on the outside, as shown at *c d*, to provide for turning. The staves are laid off with sufficient thickness to give the pattern the required strength and the lines of division between the staves are drawn toward the center *g*. The thickness of the staves *f* is determined and the polygon for the support *e* laid off as shown.

30. Cutting Stock for the Pattern. — After the drawing is completed, the polygon *e* is cut out of the drawing and used as a templet to mark the partition pieces or supports *a* and *b*, Fig. 16. The staves are then sawed to the proper angles and width from a plank that has been planed to the required thickness, as shown at *f*, Fig. 17. These staves may be sawed upon a circular saw having a tilting table as illustrated in Fig. 31, *Patternmaking*, Part 1. Two sets of supports or partitions *a* and *b* should be gotten out and doweled together after the sides are prepared.

31. Building Up the Pattern.—After the staves and partition pieces have been prepared, each half of the pattern is built up separately. If a stiffening piece *c*, Fig. 16, has been employed, it will hold the supports *a* and *b* in place and it will simply be necessary to screw and glue the staves in place. Where no stiffening piece as *c* has been employed, it will be necessary to mount the pieces *a* and *b* in their proper relation, and this may be done by surfacing a plank, drawing a line down its center, and placing the supports so that the center of their bases, as *g*, Fig. 17, comes upon a line drawn upon the plank, care being taken that the pieces are at right angles to this line. When properly placed, the supports are toe-nailed or skew-nailed to the plank, allowing the heads of the nails to project so that they may again be drawn out. After the partitions are set, a stave is fastened on each side by nailing or screwing, as desired; the joints are also glued. Other staves are added until the last stave of the half pattern is fitted, but before this stave is fastened in place, the skew nails must be drawn so as to remove the pattern from the supporting plank.

When one half of the pattern is built, the other halves of the partitions are placed with the dowels on their mates in the built-up half, which has been removed from the plank and turned over. The halves of the supporting pieces *a* and *b* may be held together by driving some dogs into them on each side of the partition. Staves are now fitted as before. In case the dogs have been used on the inside of the partitions, the last stave must not be glued in place, but can be secured by screws until the turning is complete, after which the screws can be removed, the dogs taken out, the pattern taken apart, and the stave returned to its place and glued and screwed on permanently. The advantage of placing a stiffening piece on the inside of a pattern, as shown at *c*, Fig. 16, is that it supports the inside of the partitions and reduces the liability of their being pounded out of position by the molders. It also gives the molder a convenient means for handling a half pattern.

32. Turning the Pattern.—Before turning a pattern of this class, iron plates containing centers are fastened to the partitions *a* and *b* or the ends of the planks *c* so that the centers are at the center of the pattern and in the plane of the parting line. One of these plates may be provided with a projection on one end, as shown in Fig. 29, *Patternmaking*, Part 1, which serves as a driver for revolving the pattern. This plate, with the projection, is called a tail-dog. Both plates are provided with cone-shaped centers to receive cone-shaped lathe centers. As the plate at the tailstock end revolves around a fixed center, it should be well oiled where the contact occurs. Sometimes, pieces of hard wood are placed upon the pattern instead of the metal center plates, and, in this case, a pin is fastened upon the end of the pattern to serve as a dog or driver. After all is ready, the piece is turned so as to form a plane cylinder like the portion between the lines *a b* and *c d*, Fig. 15.

33. Preparation of the Flanges.—The flanges for the ends may be made as follows: Two pieces of stock

of sufficient size to make the flange are prepared by planing one face and one edge smooth and joining the edges together. The joined edges are put together and the center of the surface so made is found as at *a*, Fig. 18, *b c* being the jointed face between the two blocks or pieces of wood. With the point *a* as a center, a circle is scribed having a diameter slightly greater than that of the finished flange and pieces are cut to this line with a band saw. The edges may now be glued together with a strip of paper between them, so that the turning operation may be more safely performed, although this is not always done.

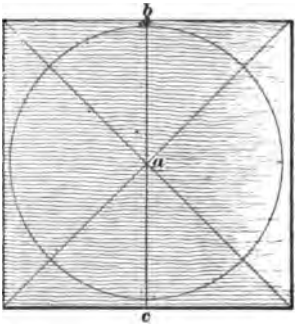

FIG. 18.

The pieces are then fastened to a large face plate, as shown in Fig. 19 (*a*), the marked center *a*, Fig. 18, being placed carefully in the center of the plate. The flange is then turned to the form shown in Fig. 19 (*b*). The fillet joining the flange to the body of the pattern may be turned

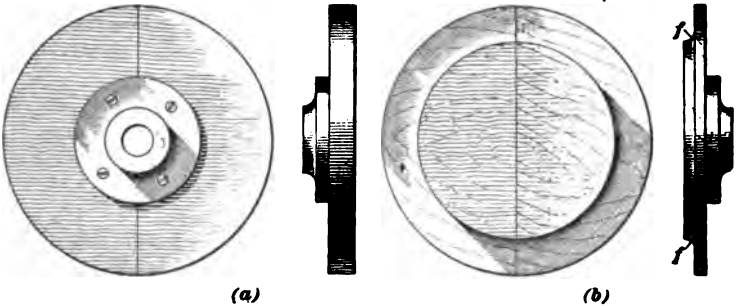

FIG. 19.

on the flange as shown at *f*, Fig. 19 (*b*). A slight taper for draft ought to be given from this fillet to the outside edge of the flange; a taper for the same purpose should be given to the other side of the flange by first marking on the revolving disk a line where the outside of the core print

will come and tapering the flange from this line to the outer edge.

34. Core Prints.—The core prints are turned from pieces of stock that have been joined together and are usually solid. The ends are rounded a little for draft, as shown at *e*, Fig. 15. The prints are fastened to the flanges with screws and glued as shown in Fig. 20, *c* being the core print and *a* the flange. After the flanges and core prints have been fastened to each other, the flanges are secured to the body of the pattern by means of screws and glued, as shown in Fig. 20, *b* being the end of the body of the pattern. Where a supporting board *c*, Fig. 16, has been used in the pattern, it is sometimes made long enough to let into the core print *c*, Fig. 20, thus strengthening the entire pattern. When the board *c*, Fig. 16, is of the same length as the staves of the pattern, it may be secured to the core print and flanges by placing suitable blocks on the inside end of the core print and flanges and screwing or gluing them to the board.

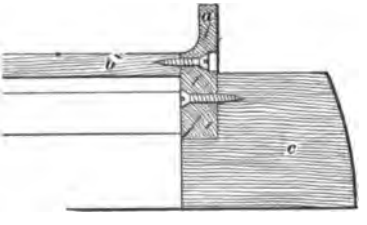

FIG. 20.

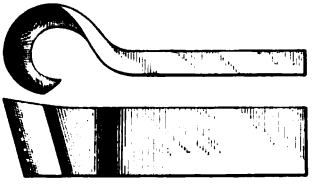

FIG. 21.

35. Special Tool for Turning Large Patterns.—When large and heavy work is to be turned in the lathe, it is sometimes difficult to do good work with hand tools, and a slide rest may be employed. In this case, a tool of the form shown in Fig. 21 can be used for turning the pattern. This form of tool is not only suitable for roughing, but will do very good work on a finishing cut if the feed is not too coarse. The tool is usually fed along the slide rest by hand.

CORE BOXES FOR CYLINDRICAL AND TAPERED CORES.

36. Small Core Boxes.—When small cylindrical cores are required, a core box of the form *b* and *c*, shown in Fig. 22, may be made in cases when the core *a* is of such proportions that it can stand on end while being dried. To make such a core box, two pieces of stock are cut a little

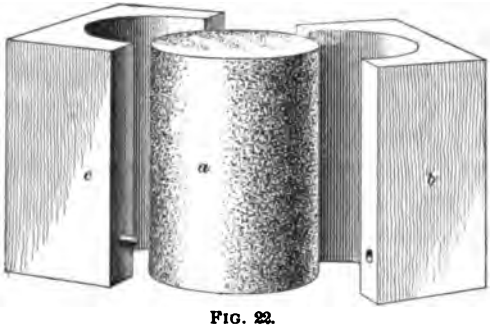

FIG. 22.

longer than the required length of the core, or of such a size as to leave ample stock for strength after a space for the core has been cut out. The pieces are doweled and clamped together, after which the ends are squared and the

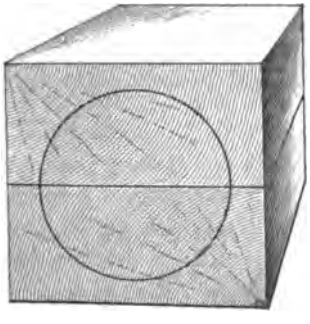

FIG. 23.

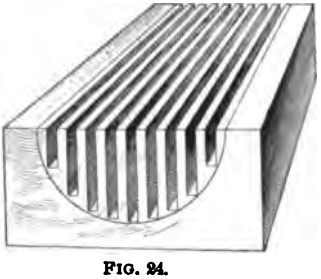

FIG. 24.

pieces cut to the exact length. Next, a circle having a diameter equal to that of the required core is marked on each end, care being taken to locate the circles equal distances from one side and to have the centers on the line

of division between the two pieces, as shown in Fig. 23. The pieces are then taken apart and lines drawn across the face of each piece joining the ends of the half circles. The material between these lines then is cut away to the shape of the half circle. The bulk of the stock can be removed by means of a circular saw, the saw being adjusted to take a series of cuts, as shown in Fig. 24. After this, the work can be finished with the aid of a gouge or a circular plane.

37. Tapered Core Boxes.—When a box is required for a tapered core, it is usually possible to produce the core by making a half box only, as shown in Fig. 25. The construction is as follows: A piece of wood having a length equal to the tapered portion *a b* is gotten out. The width and thickness of the block should be sufficient to allow ample stock about the large end of the taper, as shown at *a*. A center line should be drawn along the length of the upper face of this block and half circles drawn on the ends *a* and *b*.

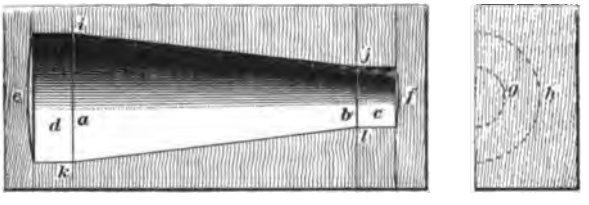

FIG. 25.

The radii used in drawing the circles should be such that the ends of the box will have the desired form, as shown at *a* and *b*, and by the dotted lines at *g* and *h*. The ends of these semicircles should then be joined by lines *i j* and *k l*, after which the stock may be worked out to the desired form by means of gouges. It is impossible in this case to remove the greater part of the stock by sawing, as illustrated in Fig. 24. The condition of the work may be judged by first working the material out to the circles on the ends and then using a straightedge through the box. After the tapered portion is complete, the pieces *c* and *d* for the prints are gotten out.

These can usually be turned upon the face plate, one-half of the block being used in each case. The ends *e* and *f* should always have recesses turned in them, as shown, to allow draft at the ends of the core.

38. Large Core Boxes.—Boxes for plain round cores of large dimensions can be built up with staves in a manner similar to that employed in building up large cylindrical patterns. A core box of the form shown in Fig. 26 can be built up in this manner. Fig. 27 (*a*) illustrates a section of the core box showing the general construction and Fig. 27 (*b*) shows the method of putting the frame together. The supports *a* are shaped out with a band saw to the desired form, a templet being used as in the case of large cylindrical built-up patterns. The staves are also made as in the case of large cylindrical patterns, but in this case it is the inside face of the stave that is to be dressed off round instead of the outside face being turned smooth. This dressing may be done to the individual staves before they are fastened in place, as shown in Fig. 28, *a* being an end view of one of the staves showing the manner in which saw cuts may be used for

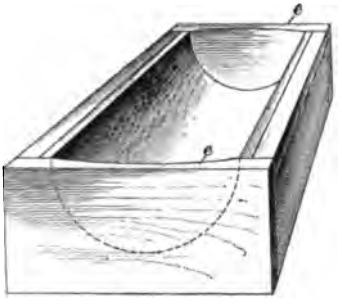

FIG. 26.

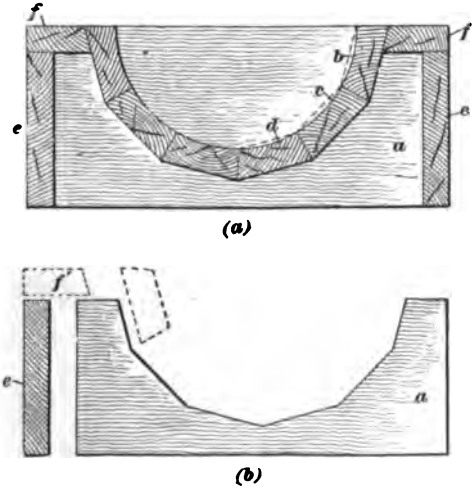

FIG. 27.

removing a part of the stock. The templet *b* is used in finishing the inside curve of the stave. This templet is provided with a shoulder *c* so that it can be used in drawing the curved line shown on the end of the stave at *a*, as well as for testing the curve when the work is finished.

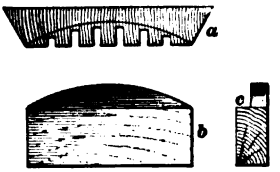

FIG. 28.

After the staves have all been formed to the correct shape, they are placed upon the supports *a*, Fig. 27, and screwed or nailed and glued in place, *b c d*, Fig. 27 (*a*), illustrating the staves. The outside of the core box is then enclosed in a suitable framework composed of the pieces *f* and *c*. If the core is long, it will be necessary to use a number of supporting boards *a*. The inside of the ends of the box *e*, Fig. 26, should be provided with sufficient draft so that the core can easily be removed from the box. These ends are usually made from thick plank, and the draft is turned upon them while they are attached to the face plate of a lathe.

PATTERNS AND CORE BOXES FOR BENT PIPES.

39. Half-Circle Pipe Bend.—This style of pattern may be taken as typical of that class which is circular in both cross-section and outline. In the construction of this class of patterns, nearly all the work may be performed on the lathe. The pipe bend shown in Fig. 29 is a good illustration of this style of casting.

FIG. 29.

40. Preparation of Stock and Face Plate for Turning.—To make a pattern for the pipe bend shown in Fig. 29, a circular disk of wood, slightly greater in diameter than the outside of the pattern, is first sawed out. This is to be used as a chuck in the lathe and must be fastened

to the face plate so that its face can be turned smooth and flat. After the chuck is prepared and turned flat, a piece of thick paper is glued over the face. When the glue has dried, the center is marked while the chuck is revolving.

The material for the body of the pattern is prepared by getting out two pieces of stock slightly thicker than half the thickness of the finished pattern and large enough so that the outline of the pattern will go inside of the outer edge, as shown by the lines in Fig. 30 (*a*). The two pieces are planed smooth on one face and jointed on one edge of each, as shown. The jointed edges are placed together and a circle slightly greater in diameter than the finished pattern

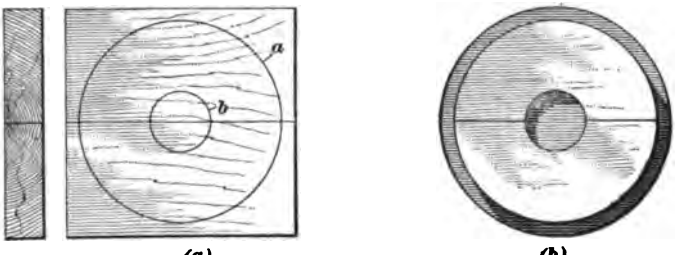

FIG. 30.

is marked on the faces, as shown at *a*. The corners of the pieces are sawed off to this mark. It is also good practice to draw the circle *b* with a radius slightly less than that of the inside of the bend and then remove the stock from the inside of this circle with a saw. After the pieces are thus prepared, they are glued to the paper on the face plate, the jointed edges being set at the center of the chuck, this adjustment being made possible by means of the center mark that was made while the chuck was revolving.

41. Turning the Body of the Pattern.—After the glue has dried, the chuck is placed on the lathe and pencil marks are made on the face of the wood for finding the inside and outside diameters of the pattern, after which the faces determined by the lines *a* and *b* already referred to are cut straight in to meet the chuck. The work will now be of

the form shown in Fig. 30 (*b*). The rectangular section is then turned to a semicircular form as shown in Fig. 31, a templet being used to determine the exact form desired.

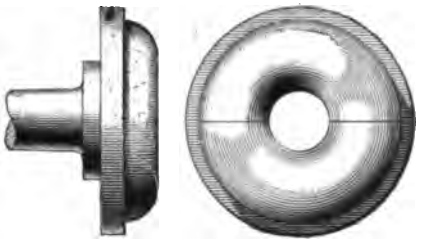

FIG. 31.

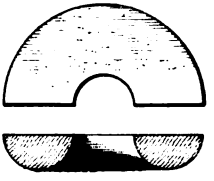

FIG. 32.

The pattern is then varnished and removed from the chuck, when each piece will be of the form shown in Fig. 32.

42. Flanges and Core Prints.—The flanges and core prints can be made together. To accomplish this, two pieces of stock having a width slightly greater than the diameter of the flange and a thickness slightly greater than half the diameter of the flange are finished and jointed

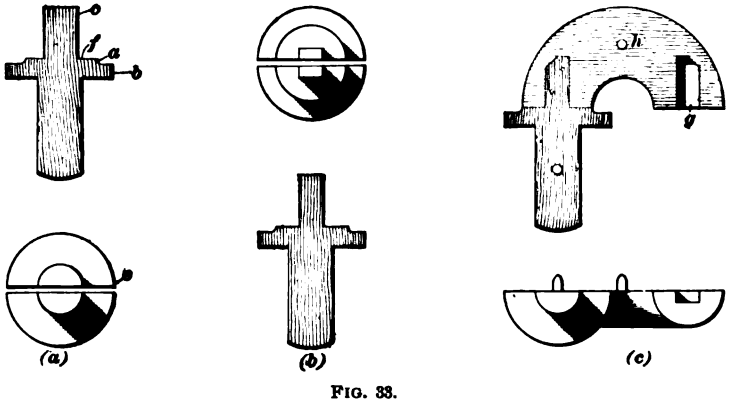

FIG. 33.

together. They are then turned to the form shown at *e*, Fig. 33 (*a*). There are two pairs of these flanges and prints required for the pattern, and it is well to put one pattern pin in each pair before turning. The fillet *a* is turned with

the flange *b*. Inside of the face *f*, a projecting piece *c* is turned, as shown. This projecting piece is employed for joining the print to the balance of the pattern. The print and flange are smoothed and varnished before they are taken from the lathe, care being taken to color the print a different color from that employed on the flange and the balance of the pattern. The projecting piece *c*, by which the flange is to be attached to the body of the pattern, is made rectangular after the work is taken from the lathe, as shown in Fig. 33 (*b*).

To attach these parts to the pattern, the projection is laid in place on the body of the pattern and the outline carefully marked on the pattern with the pencil. With this outline as a guide, a recess is cut to receive the projection, as shown at *g*, Fig. 33 (*c*). The pieces are attached to the body of the pattern by means of screws and glue, as shown in Fig. 33 (*c*). Care must be taken so that the halves of the flanges and prints come exactly opposite each other. Usually, three dowel-pins are used, two as already stated, one in each print, and the third is placed in the body of the pattern, as shown at *h*, Fig. 33 (*c*). In the case of small-sized bends of this character, the prints are made long, as shown, in order that the portion of the core in the print may balance and hold firmly the overhanging portion in the mold.

43. Core Box.—The core box for a small pipe bend may be made as a half box of the form shown in Fig. 34, the operation being as follows: The stock for the curved portion of the box must be thick enough to leave the box amply strong after the recess for the core has been cut, and long enough to allow the curved outlines of the core to come well inside the edges of the box, as shown at *f*, Fig. 34. Sometimes the end of the box is cut off to a curved outline, as shown by the dotted line, but ordinarily the corners are left square, as shown in Fig. 34. Fig. 35 illustrates the manner of laying out the piece. The piece is attached to a wooden chuck on the face plate of the lathe, as was done in turning the pattern, or in some cases it is screwed directly

to the face plate, care being taken that the screws will not interfere with the turning.

The face of the block is first turned smooth and true, after which two circles are marked on it as it revolves to locate the inner and outer edges of the core. These circles are

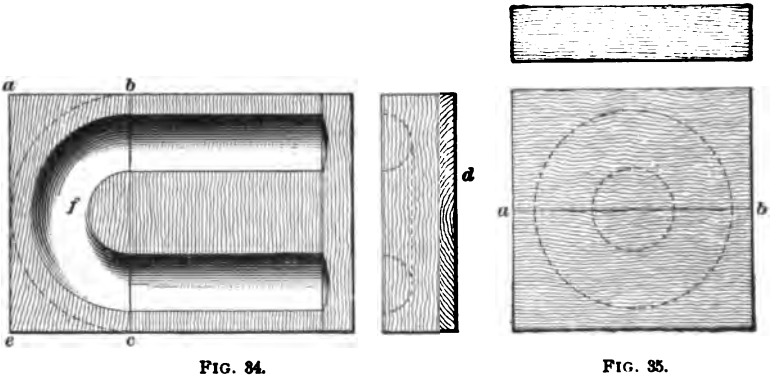

FIG. 34. FIG. 35.

shown by the dotted lines in Fig. 35. The line *a b* should also be drawn through the center of the block and is used later when sawing the block apart. The semicircular groove for the core is turned out to the desired form. This form may be determined by means of a templet of the form shown in Fig. 36. Before taking the piece from the face plate, it should be smoothed and varnished.

FIG. 36.

After the piece is completed, it is taken from the face plate and sawed in two on the line *a b*, which was drawn through the center. Care should be taken that the line comes just on one edge of the saw cut, so that this piece will contain a portion of the groove forming a full half circle. The piece will now be of the form shown by the block *a b c c*, Fig. 34.

44. In order to form the straight portion of the core box, a piece of stock of the same thickness and width as that which has been used for turning the curved portion, and having a length sufficient to form the straight portions of the core, is next cut and shaped to the form shown in

Fig. 37 (*a*). The position and depth of the grooves *a* and *b* may be marked on the ends by setting this piece against the piece that has just been turned, as shown in Fig. 34, and marking from the groove in that position.

The depth and shape of the groove may be regulated by a templet similar to the one used in turning, and shown in Fig. 36. The turned piece and the straight piece are next fastened together with glue along the line *bc*, Fig. 34. To close the other end of the straight piece, a third block of the form shown in Fig. 37 (*b*) must be gotten out. This block is placed against the straight portion, as shown in Fig. 34, and curves marked so that the clearance spaces *a* and *b*, Fig. 37 (*b*), can be worked out. This piece is sometimes made in two portions, the pieces being joined together, attached to the face plate of a lathe, and the clearance turned into them, this usually being easier than forming it with hand tools. When the end shown in Fig. 37 (*b*) is completed, it is glued on to the box as shown in Fig. 34.

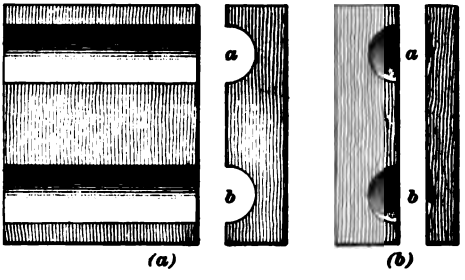

FIG. 37.

45. If it is desired to further strengthen such a box, this may be done by fastening a piece of board upon the back, as shown at *d*, Fig. 34, or strips may be fastened along the sides across the three pieces. Such strips are usually attached with screws. If a box of this class is to be used much, it is well to have the grain of the wood in the different pieces run in the same direction when practicable.

PATTERNS AND CORE BOXES FOR ELBOWS.

46. Small Elbow Pattern. — The pattern for an elbow of the style shown in Fig. 38 (*a*) can be produced by slightly modifying the methods used in making the

half-turned pipe already described. The elbow shown is provided with one socket and one spigot end. When a

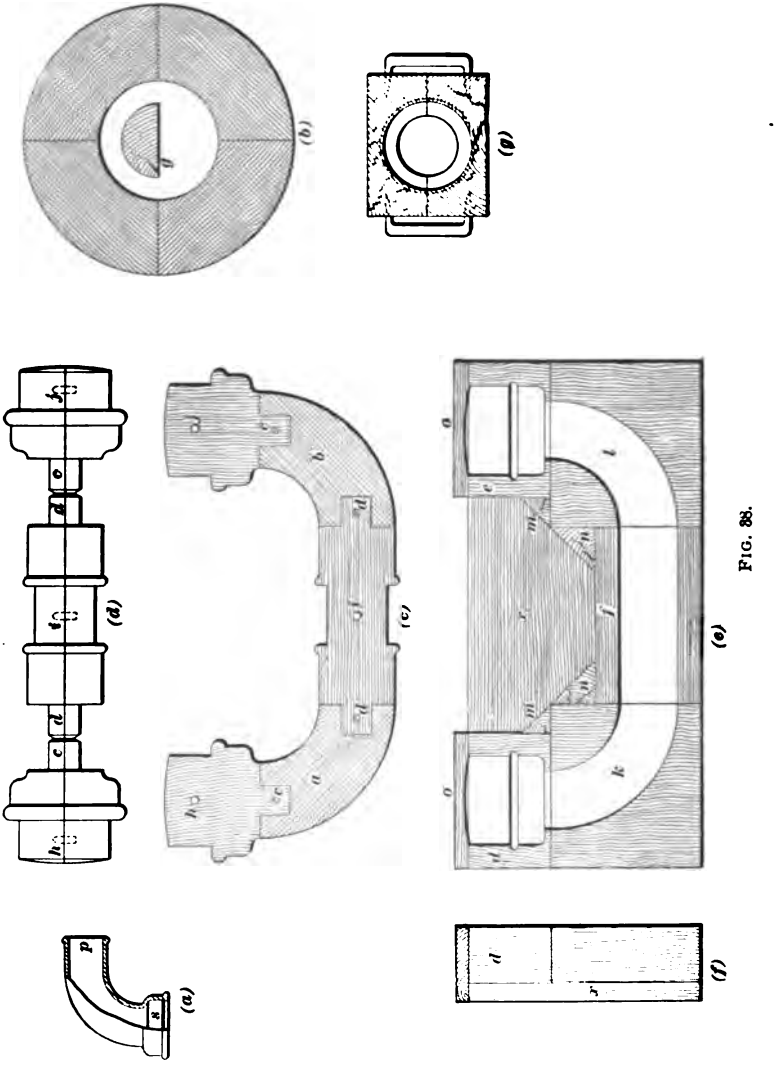

FIG. 88.

comparatively large number of such castings are required, it is common practice to mold and cast two of them at one

time, the pattern being made double, as this makes very little more work for the molder than would be required for the production of a single elbow and thus economizes both time and space in the foundry.

The different illustrations in Fig. 38 show the manner in which the pattern and core box are produced, and the following description will show that it requires very little more work to produce this double pattern than it would to produce a single elbow pattern. Another advantage is that the core balances better in the mold when a double pattern and core are used than it would if only one elbow were cast at a time.

47. The pattern is made as follows: A ring is made as shown at Fig. 38 (*b*), the cross-section being shown at *g*. This is made either by securing a solid piece to a chuck or face plate and turning to the cross-section shown at *g*, or by securing four pieces to the face plate, each piece being so secured that the grain runs in the direction of its length, as shown in the illustration. When this latter method is employed, the joints between the four pieces are carefully made so that when the work is turned and taken from the chuck, it will be complete and the ring will not have to be sawed into four pieces. The cross-section of the ring may be brought to the proper form by the use of a templet made of wood or metal. If the ring has been turned from a solid piece, it is then cut in quarters and the quarters are used for the part of the pattern marked *a* and *b*, Fig. 38 (*c*). It is always best to have the grain of the pattern running in the direction shown at *a* and *b*, and for this reason it is best to turn the ring from four pieces, the grain of which runs in the direction shown at Fig. 38 (*b*).

After the curved portions for the elbows are finished, the portion of the pattern to produce the socket *s* and the spigot *p*, Fig. 38 (*a*), may be made as follows: These portions and the core print can easily be made at one time, providing the pattern is not of excessive size. Two pieces of stock, having a width slightly greater than the diameter of

the socket *s* and a thickness slightly greater than one-half its width, are surfaced and jointed together. One dowel should be placed in the center, as at *i*, Fig. 38 (*d*), and one dowel near each end, as at *h* and *j*. These last dowels should come in the core prints at the socket ends of the elbows. After the pieces are glued up with paper between them, they are turned to the form shown in Fig. 38 (*d*), the fillets for the socket *s* and the spigot *p* being turned right on the stock. The projections *c* and *d* are intended for joining the parts to the curved portions of the pattern. After the pattern is completed, the pieces are sawed apart between *c* and *d*, the ends *c* and *d* dressed to a square cross-section and let into the curved portions as shown at *c* and *d*, Fig. 38 (*c*). This work must be done accurately so that the dowels and portions of the pattern will all come opposite each other as they should.

48. Core Box for Elbow Pattern.—After the pattern is built, the core box is made as shown in Fig. 38 (*e*) and (*f*). The box can be put together in sections, as shown, and, as the core is symmetrical, it will only be necessary to make one-half of the core box. The blocks for forming the portions *k* and *l* are turned to form in a manner similar to that employed in producing the curved portion of the core box shown in Fig. 34, only two quarters of the block being used. The straight portion *f* is produced in a manner similar to that employed in producing the straight portion of the core box shown in Figs. 34 and 37 (*a*). The straight portion *f* furnishes both the core for the straight portion of the spigot and for the print between the two spigot ends of the pattern. The portions of the box to form the core for the socket ends *s*, Fig. 38 (*a*), must be turned in the lathe. Two blocks are joined by means of dogs, as shown in Fig. 38 (*g*), or by means of screws. They are then fastened to a face plate or chuck and turned out to the required shape. A templet can be used to give the proper form and to locate the ring inside of the end of the socket. When these pieces are

turned, they are glued to the curved blocks, as shown at *d* and *e*, Fig. 38 (*e*). The ends of the prints may now be closed by the boards *o*. These must either be provided with draft or made removable so that the core can easily be removed from the box. In order to strengthen the box, the board *x* may be glued and screwed on the back, and, in addition, corner blocks *m*, *n* may be glued into the corners, as shown at Fig. 38 (*e*).

49. Large Elbow Patterns and Core Boxes.—When large elbows are required, the patterns may be built up from curved staves, as shown in Fig. 39, the staves being cut from the lumber as shown in Fig. 40, as this will bring the grain in the proper direction and at the same time save material. The finished pattern is worked down to the proper cross-section by hand tools, the shape

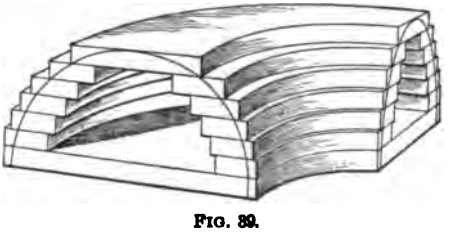

FIG. 39.

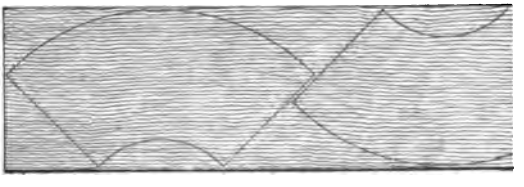

FIG. 40.

being determined by templets. The cores for these large elbows are usually swept up. A description of the various classes of sweeps will be taken up later.

PATTERNS AND CORE BOXES FOR BENT PIPES.

50. Pattern for Bent Pipes.—When a pattern for a pipe having a slight bend, as shown at Fig. 41 (*a*), is required, the work may be done in a manner similar to that

employed in the making of elbows for similar pipe, with the exception that the portion of the pattern from *a* to *b* is usually of too great a radius to be turned in the lathe, and, hence, must be worked out by hand. It is not necessary to show the parts of the pattern on account of the fact that the socket and spigot and the core prints will be exactly like those illustrated in Fig. 38, but some description of the method of making the portion of the pattern from *a* to *b* may be of interest. Such patterns as this are usually not made in pairs, but singly.

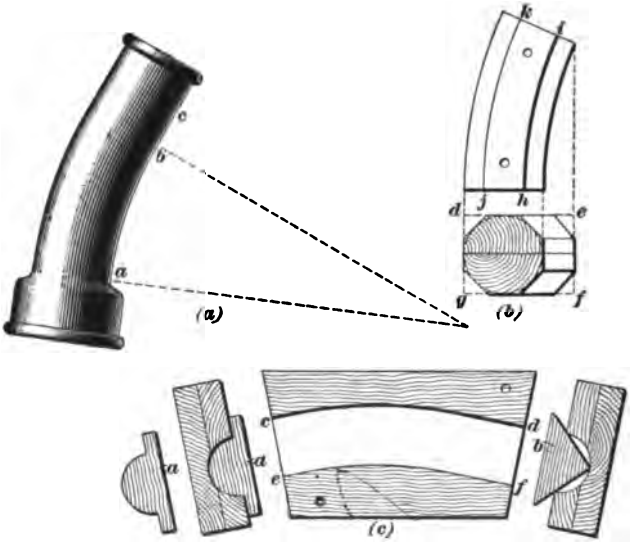

FIG. 41.

In order to make the required portion of the pattern, two blocks are fitted as shown at Fig. 41 (*b*), the blocks being secured together with dowel-pins. The stock is sawed to the correct curve, when it will have a rectangular cross-section as shown at *d e f g*. After the pieces are fastened together, a circle is laid off on each end, as shown by the dotted lines, and, with the bevel set at 45°, the full lines on the end of Fig. 41 (*b*) are marked tangent to the circle, as shown. Lines *h i* and *j k* are then drawn upon the

side of the pattern, from the points at which these 45° lines intersect the horizontal and vertical lines, as shown in the upper portion of Fig. 41 (*b*). Similar lines are drawn on all four faces of the rectangle and the stock is cut away to these lines so as to give it the form shown. After this, other lines may be drawn tangent to the circle so as to remove another portion of each one of the eight corners. These points can be continued along the faces as lines and the material between them removed, thus giving a sixteen-sided figure, and this process may be continued until the outline is approximately circular, the last dressing being done by the eye and the piece being finished to a templet. When this curved portion of the pattern is completed, the ends, with their core prints, are turned up and attached as in the pattern illustrated in Fig. 38.

51. Core Box for Bent-Pipe Pattern.—A partially completed core box for a bent-pipe pattern is shown in Fig. 41 (*c*), the portion for the socket end having been omitted. The portion of the box shown is worked out to the proper form by hand. The curved portion corresponding to the part of the pipe *a b*, Fig. 41 (*a*), is laid out upon the surface of the block, which has been prepared for the core box by means of suitable curves, and the lines representing the straight part are drawn tangent to these curves. After this portion of the laying out has been done, a half circle is scribed on each end of the block corresponding to the diameter of the required core. The stock between these two curved lines *c d* and *e f*, Fig. 41 (*c*), is then worked out to the required circular cross-section. This may be done by the aid of a templet, as shown at *a*, or by the use of a square, as shown at *b*, Fig. 41 (*c*).

There is also a special plane, which is made to operate on the principle of the square illustrated at *b*, which may be used for this purpose, the cutting being done by a narrow bit at the angle of the square. Such a plane as this is not suitable for working out the curved portions of the pattern, but for the straight portion it is very convenient.

Frequently, such a core box as this is made in three parts, each one of the straight parts being made separate so that most of the stock can be removed on a circular saw, the portion for the curved part being made separate. After the core box is finished as shown in Fig. 41 (*c*), the piece for the end is turned up and put in position, this piece being similar to that shown at *e* or *d*, Fig. 38 (*c*). Owing to the fact that this core is not symmetrical, it will be necessary to make both halves of the core box.

PATTERNS AND CORE BOXES FOR BRANCH PIPES.

52. Pipes Having Branches at Right Angles to the Body.—The patterns for branch pipes have many features in common with the bent pipes that have already been described. The only difference presenting difficulty in making this class of patterns lies in the forming of the joint between the main body and the branch piece.

When the body and the branch have the same diameter, and stand at right angles to each other, as illustrated in

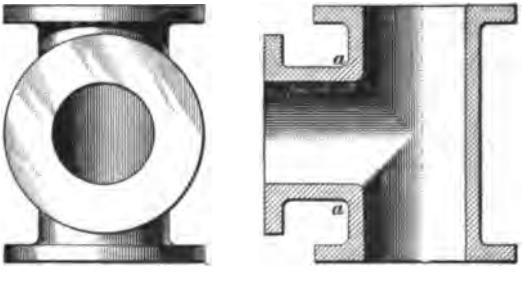

FIG. 42.

Fig. 42, the following construction for the pattern may be used for medium-sized and small patterns. The stock for the branch and the body is gotten out and doweled together as in the case already described, after which the two pieces may be turned to the form shown in Fig. 43 (*a*). The piece *a* for the body has a core print turned at each end, while the piece *b* for the branch has only one core print and the

opposite end is left square. The distance *c d* on the branch pattern should be equal to just half the length *e f* when the branches are all to be of the same length. The distance *e f* is not made equal to the entire length of the main body of the pattern, but is shorter by an amount equal to twice the width of the flanges and the part necessary to make the fillet back of the flange.

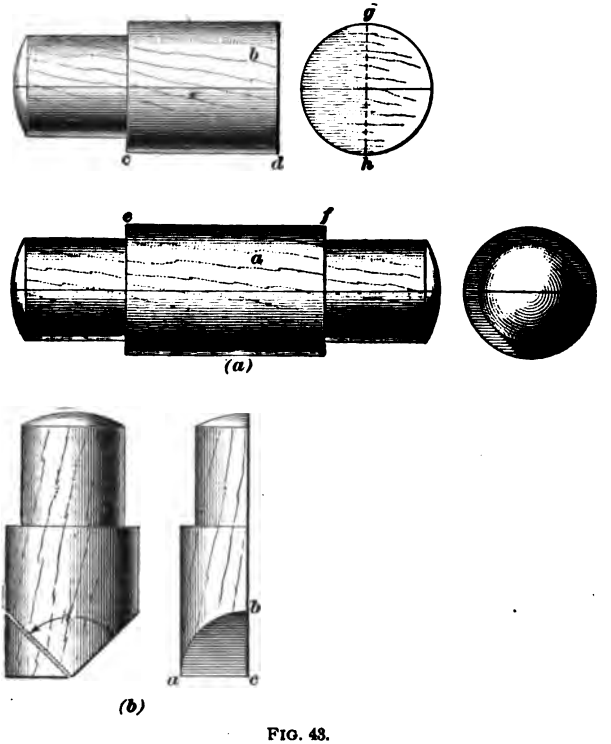

FIG. 43.

After the pieces are turned, the line *g h* is drawn across the end of the branch pattern at right angles to the joint between the two pieces. The corners of the pattern are next cut off to this line, as shown in Fig. 43 (*b*), the angle *i* being made 90°. Some patternmakers cut the corresponding 90° from the center of each piece of the body and then join the parts together, but, in the pattern shown, the joint is made

by cutting out the piece *a b c*, Fig. 43 (*b*), and then joining the branch against the body of the main pattern. The part *a b c* may be removed by clamping half of the branch pattern to a block, as shown in Fig. 44, after which the piece *a b c* can be removed by means of the band saw.

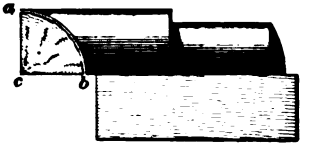

FIG. 44.

53. The branch and body are fastened together by means of glue and screws. The operation is made easier by applying the glue first and then clamping them to a board while the glue is setting, as shown in Fig. 45 (*a*). A piece of heavy paper should be placed between

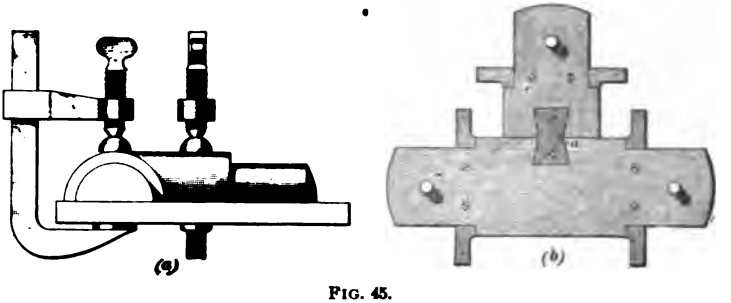

FIG. 45.

the board and the pattern to prevent the latter from adhering to the former. To further strengthen the joint, a dovetailed piece may be set in flush with the face of the pattern between the branch and the body, as shown at *a*, Fig. 45 (*b*).

54. The flanges may be turned to the form shown in Fig. 46, the opening through the center being made of such diameter that it will just fit the core prints. The fillet between the body of the pattern and the flange is turned upon the flange. The method of joining these flanges to the pattern by means of screws is shown in Fig. 45 (*b*). In this pattern, the dowels are usually put in

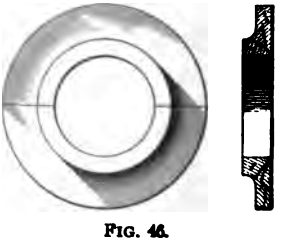

FIG. 46.

the three core prints, as shown. The fillet at *a*, Fig. 42, may be made of leather or wax.

55. Core Box for Pipe Having Branches at Right Angles to the Body.—The core box used for this style of pattern does not differ materially from those already described and is of such form that it can be very easily constructed. Fig. 47 illustrates the core box for the casting shown in Fig. 42. It will be noticed that it consists almost entirely of straight work. The portion between the lines *a b* and *c d* of the main body and between *a c* and *e f* of the branch can be worked out by removing the major part of

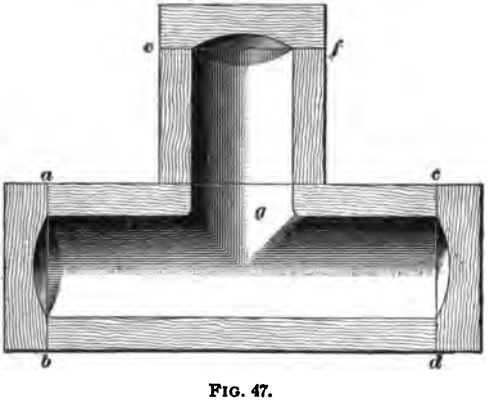

FIG. 47.

the stock with a circular saw and finishing with gouges. A small portion of the branch at *g* can be formed by placing the finished branch box against the outside of the portion for the body, and marking the curve upon the latter, after which lines may be squared across the surface of the body and the portion removed by means of gouges or chisels. The ends for the core boxes are provided with draft as usual, and the entire structure may be strengthened by screwing or gluing a board on the back.

56. Patterns for Pipes Having Branches Not at Right Angles to the Body.—When branch pipes of the form shown in Fig. 48 are required, the method of procedure

is somewhat different from that already described, the principal difficulty being to determine the form of the joint between the branch and the main pipe. The parts for the pattern may be turned out in a manner similar to that illustrated in Fig. 43, although in this case it is probable that the sockets and core prints would both be turned on the parts of the patterns.

In order to determine the form of the joint between any two cylindrical sections intersecting at an angle, the following method of laying out may be employed: On a piece of heavy drawing paper, lay off the outlines of the stem and branch in their proper relative positions, full size, as shown in Fig. 49, *i* being the main pipe and *j* the branch. All the drawing must be done carefully with fine pencil lines. Above the plan, a line *k c* should be drawn perpendicular to a center line of the body of the pattern, as shown at *l m*. Upon this line describe the semicircle *k m n* equal in diameter to the main body of the pattern, and at one side erect a perpendicular *1 b* and upon it describe the semicircle *a b c*, equal in diameter to the branch pipe. Taking any point on the branch section, as, for instance, the highest point directly over *1*, draw the line *b b'* parallel to *c k* until it intersects the circle *k m n* at *b'*. This determines a line on the surface of the body of the pattern at the top of the intersection with the branch. Draw the line *b' b''* and somewhere in this line, on the body of the pattern *i*, can be found the highest point of the intersection between the main body and the branch. On the end of the branch lay off the point *1'* in the center of the line *a' c'* and draw the line *1' b''* along the center of the branch *j* to where it intersects the line *b' b''*, which will give the desired point *b''*.

FIG. 48.

Proceed in like manner for any other point, but, in all other cases, two points will be obtained at each time, owing to

the fact that any other plane nearer the line *k c* will intersect the branch in two points, as, for instance, if the point *2* is selected and the distance from *1* to *2* is made equal in both drawings, and a perpendicular *2 e* drawn until it intersects the curve representing the cross-section of the branch. By drawing the line *e e'* parallel to *k c*, an intersection of the circle *k m n* at *e'* is obtained, and then the line *e' f''* is drawn parallel to the center line *l m*. Now, lay off on the line *a' c'*

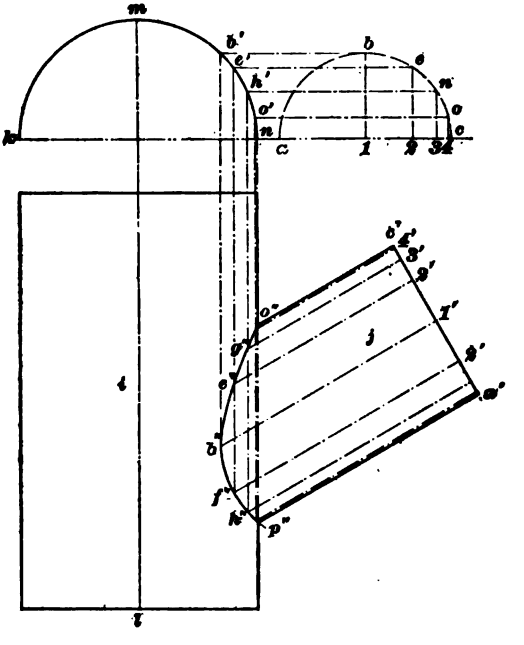

FIG. 49.

the distances *1'–2'* each side of the center, and through these points draw lines parallel to *1' b''*. These will intersect the line *e' f''* at *f''* and *e''*, giving two more points in the intersection. In like manner, by taking points *3* and *4* and carrying the lines around as shown, the points *g''*, *h''*, *o''*, and *p''* may be obtained. A curve *o'' b'' p''* is then drawn through these points.

When the curve marking the intersection of the two parts has been drawn, the paper must be carefully cut to this line, thus forming templets for marking both the body and the branch. These templets are laid on the face of the branch and body and the proper curve drawn on each. The portions on the branch and body of the pattern defined by these curves may be cut out on the band saw if the parts are so held that the flat face is parallel with the top of the saw table. To accomplish this, a form like the one shown in Fig. 50 may be made and the pattern clamped into it so that the face *a* of the pattern is parallel with the saw table. After the pieces have been cut to the curves, the branch and body are fitted together closely and glued in place. Frequently, dovetailed pieces similar to that shown at *a*, Fig. 45 (*b*), are employed for securing the pieces together, and a leather or wax fillet is placed on the outside at the junction between the branch and the body of the pattern.

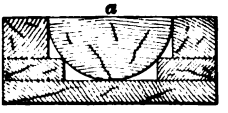

FIG. 50.

57. Core Box for Pipes Having Branches Not at Right Angles to the Body.—Owing to the fact that the

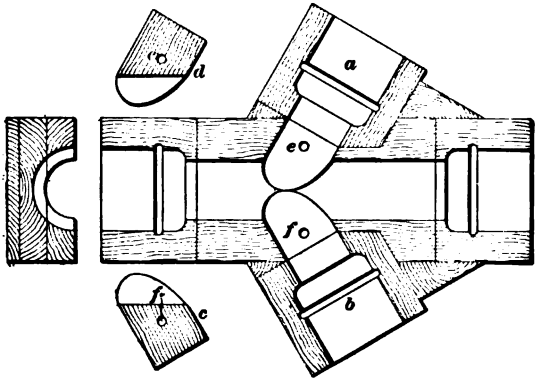

FIG. 51.

casting illustrated in Fig. 48 is not symmetrical, it will be impossible to use a half-core box unless some special provision

is made for obtaining both halves of the core. Fig. 51 illustrates a special style of core box that may be used in such cases as this. The core box is constructed with two branches *a* and *b* and both branches are provided with stop-off pieces *c* and *d*, which can be put in place and secured by pins in the holes *e* and *f*. For making one half of the core, one of the stop pieces is employed, and for making the other half, the other stop piece is employed. The other features of the box are so similar to those already described that it will not be necessary to consider them in detail.

BUILT-UP ANNULAR PATTERNS.

58. Advantages.—When large patterns having the general form of flat rings, similar to the one shown at Fig. 52 (*a*), are required, they are commonly built up of segments. Such patterns are used for making pulley rims, ring forms, and for similar purposes. If the pattern is comparatively small and for temporary use, it is occasionally turned from one piece, as shown in Fig. 52 (*b*), but in this case the grain will run across the pattern along the line *a a*, and, if the ring is thin, there is great danger of it breaking at this point, unless considerable care is exercised in its use. The shrinkage of the wood is always across the grain, and, hence, such a pattern as this would soon become smaller across the diameter *b b* rather than across the diameter *a a*, and the form would become elliptical. For these reasons, ring patterns are rarely turned from solid stock. Ring patterns must be turned on some form of large face plate. These face plates are generally made of wood.

59. Preparation of Wooden Face Plates.—Before turning an annular pattern, it is necessary to prepare a wooden face plate upon which to build it up, and also to use as a support during the turning. The manner of making this face plate depends on the diameter of the pattern to be turned. In the case of patterns not over 20 inches in

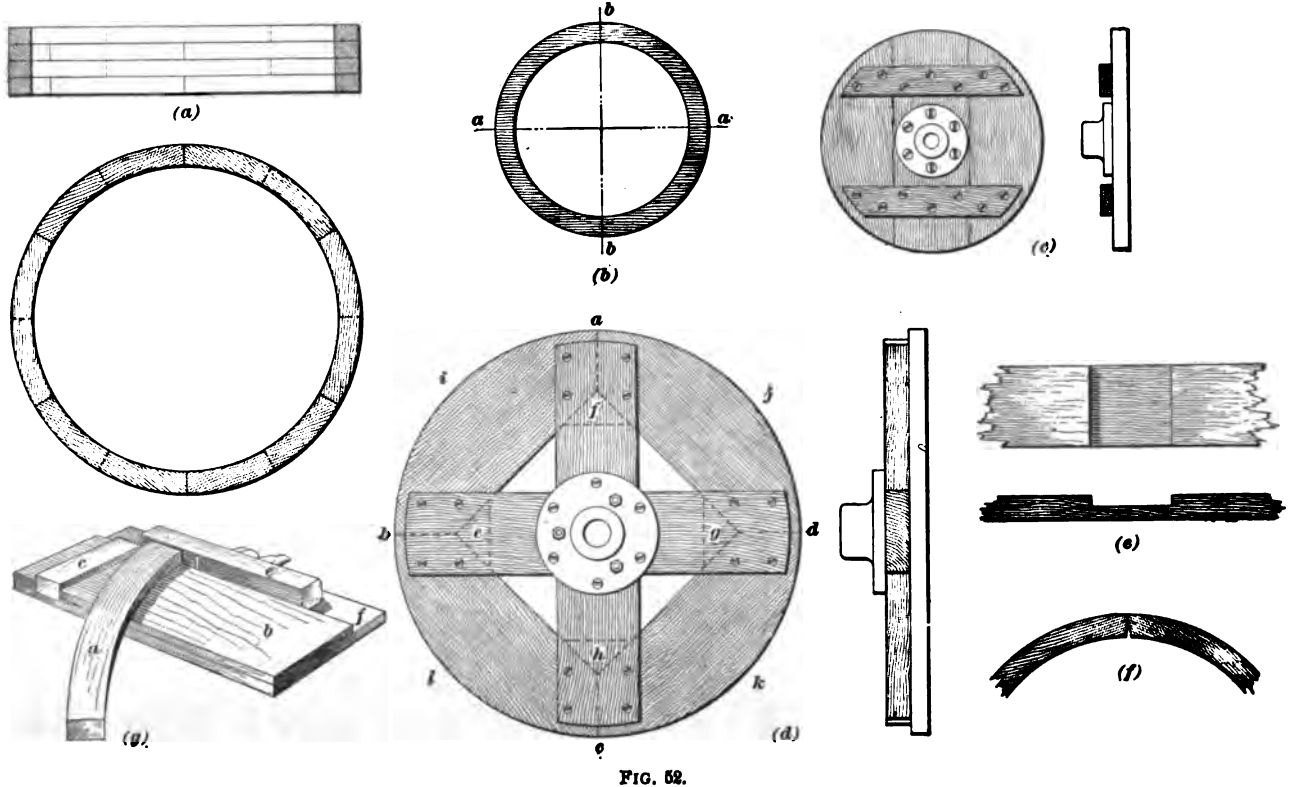

FIG. 52.

diameter, the face plate may be built of strips supported by cleats on the back, as shown at Fig. 52 (*c*). Heavy screws must be used for securing the cleats and for fastening the iron face plate to the wood. For ordinary work, No. 18 screws of such a length that they will permit the surface to be faced off several times before the chisel comes in contact with them, are suitable.

60. Wooden face plates of large diameter may be constructed as shown in Fig. 52 (*d*). Two or more cross-pieces are placed across the face plate, and, in case two are used, they are halved together as shown in Fig. 52 (*e*). The iron face plate is secured to these cross-pieces by means of screws and bolts. The ends of the cross-pieces can then be faced off so that they will run true when revolving in the lathe. The cross-pieces should be so balanced that they will not shake the lathe badly when the work is running. Care must be taken not to catch the turning tool in the cross-pieces while facing them.

After the cross-arms have been faced, the four segments *i*, *j*, *k*, and *l* can be fitted to them. The segments should be carefully fitted at *a*, *b*, *c*, and *d*, and firmly screwed and glued to the cross-arms. The segments should be made in such a manner that, when they are put together, the circle formed by them will be at least 1 inch larger in diameter than the length of the cross-arms. In order to strengthen the entire structure, four corner pieces *e*, *f*, *g*, and *h* may be fitted on the arms between the segments. After the glue is dry, the face plate may be turned off and faced true, when it is ready to have the pattern built up upon it.

61. Building Up of Ring Patterns. — It will be noticed that the plain ring pattern shown in Fig. 52 (*a*) is built up of a series of segments placed one upon the other, and that the joints in any given course do not come directly over those in the adjoining course. This makes a strong pattern, as each course is made to bind the adjoining one.

The grain of the wood is made to follow the circle as nearly as possible, which makes the shrinkage of the pattern uniform, thus maintaining a true circle. Before fitting the first course on the face plate, pieces of paper at least 2 or 3 inches wide should be glued to the face plate where the end joints will come. Some patternmakers prefer to cover the entire face plate with paper.

When the segments for the first course have been made ready, the under sides of the segments are glued to the pieces of paper on the face plate, care being taken not to allow any glue to run off the paper on to the face plate so as to glue the pieces directly to the face plate. The ends of the segments must be fitted carefully, on account of the fact that if they are badly jointed, as shown at Fig. 52 (*f*), the corners will break out when the patterns are being turned on the inside. It is better that the joints should be open on the outside rather than on the inside, if they are open at all, on account of the fact that there would be less tendency for the corners to break off on the outside than on the inside, owing to the direction of the grain on the inside, as shown at Fig. 52 (*f*).

62. In order to true the ends of segments, a trimming machine may be used and this will usually give the desired finish, but when very fine joints are required, they are frequently fitted by planing on what is known as a "shoot board." Fig. 52 (*g*) illustrates this method of doing the work, the segment *a* being laid upon the board *b* against the stop *c*; the plane *e* is placed on the side so that the weight of the plane does not come upon the segment, the plane being guided by the shoulder *f*.

When the first course of segments has been fitted upon the face plate, it must be allowed to dry sufficiently to stand the strain of facing. When the glue is dry, the face plate is placed on the lathe, and a light cut taken off the surface of the segments, after which the face plate is removed from the lathe and the next course built on. When the second course is in place, and before facing it off,

the ring should be screwed to the face plate from the back, as it is dangerous to trust to the paper alone for holding the pattern during turning.

The pattern shown at Fig. 52 (*a*) has six segments in each course. This number is often increased to eight, ten, twelve, or more, depending on the diameter. When the pattern has been built up and the glue well dried, it is turned to shape in the usual manner.

PATTERNMAKING.

(PART 3.)

EXAMPLES ILLUSTRATING PATTERNMAKING.

1. Selecting Stock for Patterns.—It may seem unnecessary, after what has been said in *Patternmaking*, Parts 1 and 2, to lay emphasis on the necessity of using great care in selecting stock for patterns. In the case of a skeleton or makeshift pattern, second-grade lumber is good enough, but in the case of a pattern for machine parts, especially when a large number of castings are required, and when the pattern may have to be stored for quite long intervals, the selection of the stock becomes a very important item. In such cases, only well-seasoned and well-selected lumber should be used. It is probable that more money is wasted by the use of poorly seasoned or unsuitable lumber in patternmaking than by any other one cause affecting this part of the machinery business. The evil consequences of the use of bad lumber not only increase the pattern account of a firm, but add considerably to the cost of molding and, also, to that of finishing the castings in the machine shop, since a pattern that is warped out of its original shape because it was made of wet lumber will give the molder trouble in molding; and the casting, being like the pattern, will cause the machinist trouble, thereby increasing the cost of production in all the departments because the patternmaker was not careful enough in selecting his material.

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SKELETON PATTERNS.

2. General Consideration.—When only one casting or a very few castings are required from a large pattern, means are sometimes taken in both the pattern shop and the foundry to make the required pattern as inexpensive as possible. At times, the pattern is swept up from sand and baked, and, again, it is often made of cheap second-grade lumber in the least expensive manner. In either of these cases, the pattern is practically of one material, that is, it is made either of sand or wood. In the class of patterns commonly known as **skeleton patterns,** the pattern is made partially of wood and partially of sand.

3. Pattern for Pipe Bend.—Two views representing half of a skeleton pattern for a large pipe elbow are shown in Fig. 1. To produce a whole pattern, two boards *a* are sawed out to the shape of the pipe, including the core prints.

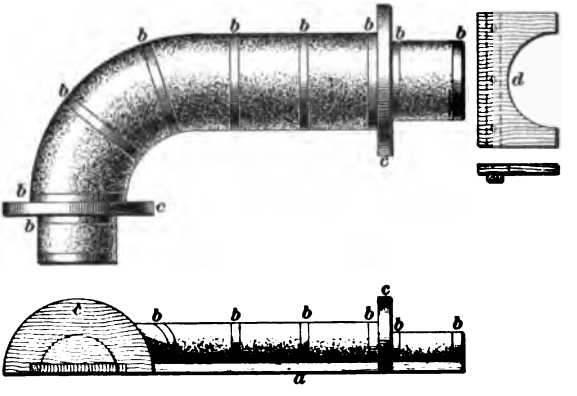


FIG. 1.

The thickness of these boards depends on the size of the pattern and varies from 1 to 2 inches. The boards are doweled together and circular pieces *b*, *b*, having the form of the cross-section of the pipe and core prints at the places where they are introduced, are sawed out and fastened upon the boards, as shown. The flanges *c*, *c* are also prepared and cut out to fit over the boards *a*.

A strike, or strickle, for each diameter of the pattern, i. e., one for the portion between the flanges and one for the core prints, are also provided for the molder. One of these strickles is shown at *d*, Fig. 1. The molder completes the pattern by laying down one of the boards, as shown in the lower part of Fig. 1, and filling the spaces between the circular pieces *b*, *b* with sand, the sand being swept off by means of the strickle, which is guided by the board *a*. When the pattern is complete, the molder sprinkles parting sand over the outside so that it may leave the mold nicely. The flask for this first half of the mold is then placed in position, rammed up, and turned over, after which the other board *a* is placed on the one shown in the illustration, its half pattern being finished up in sand, sprinkled with parting sand, and the second half of the mold rammed up. When the flask is taken apart, the cope usually draws off from the upper half of the pattern, after which the pattern is withdrawn from the mold and any loose sand that may have fallen from the pattern is removed.

4. Preparation of Core.—The core for the skeleton pattern is simply swept up by means of a guide board and strickle. These are shown in Fig. 2, *a* being the guide

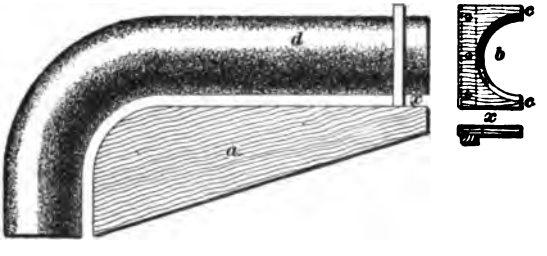


FIG. 2.

board and *x* the strickle. The guide board is clamped or weighted down upon an iron plate and the half core swept up as shown in the illustration, *d* being the core. The points *c*, *c* should be protected from excessive wear upon the iron plate by driving one or more nails into them. After one half the

core has been swept up, the guide board is turned over and the other half swept up, to match the portion already made. During the work, one edge of the strickle is kept in contact with the guide board, care being taken to see that the strickle is always perpendicular to the guide board when following its straight portions, and perpendicular to a tangent, i. e., forming a radial line, when following the curved portions. In the case of large pipes, the skeleton patterns are frequently made so as to leave a core. The pattern is a frame having the same thickness as the metal and is so arranged that strikes can be used on the inside or outside.

PATTERNS INVOLVING AUXILIARY PATTERNS.

TOOL FOR LAYING OUT HEXAGONAL PARTS.

5. In a number of the following examples, it becomes necessary to lay out a hexagonal part of the pattern, and a very convenient tool for this purpose, and one that can easily be made by any patternmaker, is illustrated in Fig. 3. This tool is made by fastening a metal plate, or plates, upon a wooden frame, as shown, *b* being a cross-section at that point. In the metal plate, an angle *fag* of 60° must be cut. The wood mounting for the metal plate must be cut to another angle *hai*. In order to find this second angle, draw the line *ac* bisecting the angle *fag*, and at any point, as *o*, draw the line *dc* perpendicular to *ac* at *o* and intersecting the lines *af* and *ag* at *d* and *c*. With a radius *od*, or *oc*, draw the circle *dcc*. Then draw the lines *ai* and *ah* tangent to the circle *dcc*. By cutting the wood to this angle,

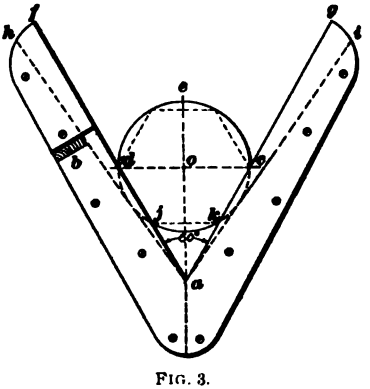


FIG. 3.

the tool is so constructed that when placed upon any circle, as shown, it will determine two sides of a hexagon, the distances *d j*, *j k*, and *k c* all being equal. The stock has then simply to be turned to the diameter over the corners of the hexagon, commonly called the long diameter of the hexagon, after which the hexagon can be laid out by using the tool, as shown in the illustration.

GLOBE-VALVE PATTERNS.

6. General Consideration.—Small **globe valves** are generally cast of brass, while the larger sizes are made of cast iron. The latter are also known as *stop valves*, and sometimes as *throttle valves*. The method of making the smaller sizes differs from that of making the larger, the former being molded by machine from several patterns attached to the plate with a gate connecting all the patterns. As many as eighteen patterns of very small-sized globe valves are often attached to one gate on the plate and molded together. When this is done, the portion of the pattern on one side of the parting line is mounted on one side of the board, and the portion on the other side of the parting line on the other side of the board, great care being required to place the portions exactly opposite each other. The methods of molding with this style of patterns will be treated in *Foundry Work*.

7. Pattern for Small Valve Body.—The method of making the pattern and core boxes for a 1¼-inch globe valve will next be considered, only one pattern being treated, although two or more may be molded in one flask. The manner of making the pattern and core boxes is the same whether one or more patterns are required, and whether they are required for matched-board work or not. Fig. 4 (*a*) and (*b*) represents two views of a globe valve, (*a*) being a section.

8. The making of the pattern for the body will be considered first. This pattern is comparatively simple, it being

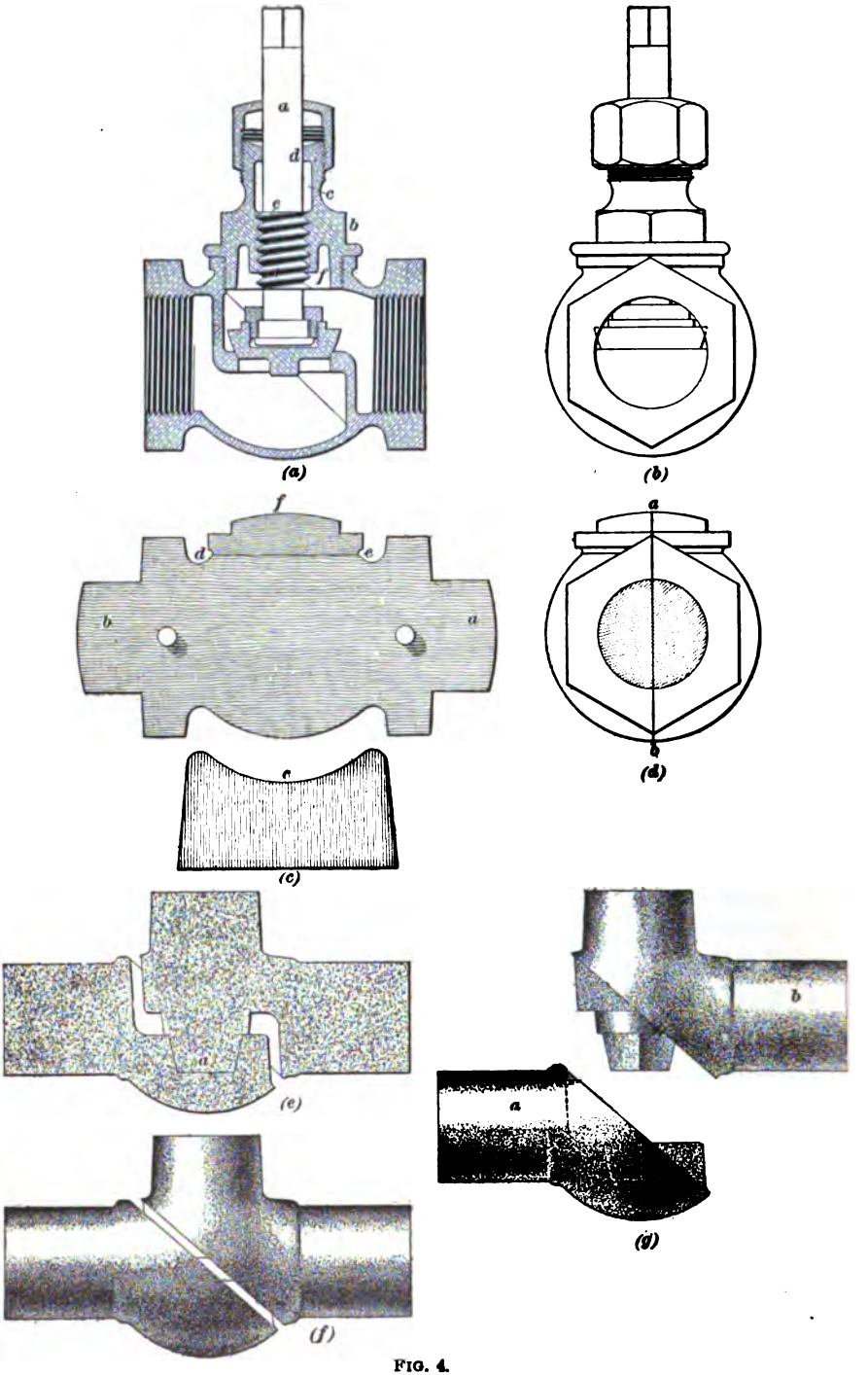


FIG. 4.

possible to turn most of it on a lathe. Fig. 4 (*c*) and (*d*) illustrates the pattern, together with several of the points in its construction. Two pieces of stock about 8 inches long, 3 inches wide, and $1\frac{1}{2}$ inches thick are cut out and jointed and doweled together carefully. The stock is made of this length in order to enable the patternmaker to glue the ends together so as to hold the pieces in place during turning. When this method is followed, care should be taken that no glue gets between the parts of the pieces that are to form the pattern. Sometimes a nail or screw is also placed in the end to aid the glue in holding the pieces together. If, however, good glue is employed, and it is allowed to dry before turning, these metal fasteners are not required in the case of small patterns.

A templet should be made as shown at *c*, Fig. 4 (*c*). This templet may be made from a board $\frac{1}{8}$ inch thick, or from a piece of sheet metal, and is used as a guide in turning the pattern to the right shape, the proper allowance being made for finish and shrinkage. The ends on which the hexagons are made are usually turned a little larger in diameter than the long diameter of the hexagon, as, otherwise, in forming the hexagon there is some danger of making it too small.

After this first portion of the pattern has been turned, the globe body must be planed off to the line *d e*, as shown, and a piece turned and glued on to form that part of the valve into which the bonnet *b*, Fig. 4 (*a*), is screwed. The two core prints *a* and *b*, Fig. 4 (*c*), are turned on the body of the pattern, and the core print for the bonnet, *f*, Fig. 4 (*c*), is turned on a piece that is glued upon the side as shown. This piece should be turned from two pieces that have been jointed and fastened together on a chuck. Care should also be taken to see that the grain runs in the same direction both in the body of the pattern and in the piece that is glued to it.

9. Varnishing the Patterns. — After turning any pattern with core prints, and before taking it out of the lathe, it is well to varnish the core prints with yellow shellac varnish. If this is not done, the unclean appearance that

they usually have as the result of handling before the varnish is applied is avoided. This precaution applies only in cases where the core prints are simply painted with yellow varnish and not with a color.

After the turning is completed, the hexagonal ends of the pattern are formed, as shown in Fig. 4 (*d*).

10. Core Boxes for the Body of Globe Valves.— The core boxes and the core that form the inside of the valve are not as easily made as the pattern. The exact shape of the core should be studied carefully before attempting to make the core boxes. In Fig. 4 (*c*) is shown

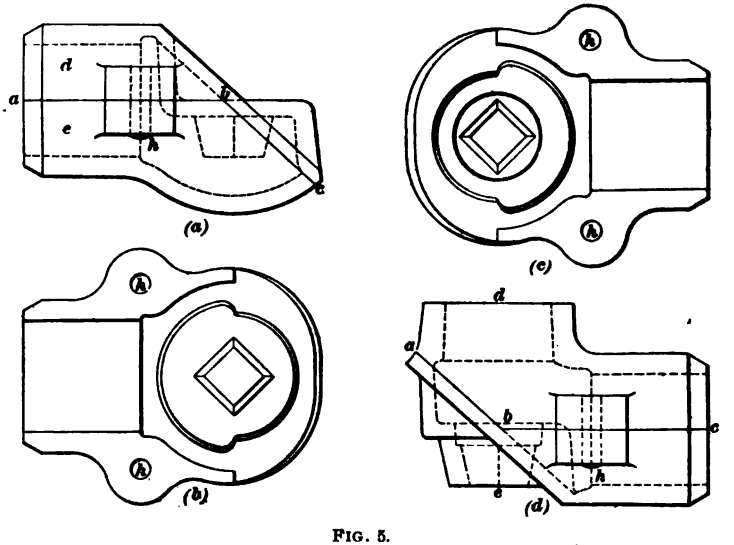


FIG. 5.

a section through the core; Fig. 4 (*f*) shows the completed core together; and Fig. 4 (*g*) shows the two parts *a* and *b* separated. It is practically impossible to make such complicated cores as these in ordinary wooden boxes, and hence it is necessary to make iron core boxes, and patterns for these must also be made. These patterns are called **auxiliary patterns.** The finished core box for making the core shown at *a*, Fig. 4 (*g*), is shown in

Fig. 5 (*a*) and (*b*), while in Fig. 5 (*c*) and (*d*) is shown the core box for making the core shown at *b*, Fig. 4 (*g*). These core boxes are usually made of cast iron or brass, nicely fitted and doweled together.

Four patterns for the boxes are made first, one for each half, and, as will be seen by referring to the inside views of both boxes, much cutting and fitting is necessary for their completion. Both boxes are parted along the lines *a b c*, and the joint between the two parts of the boxes must be made with great care, as the accuracy of the core depends very largely on it. The patterns for the core boxes should be made of well-seasoned blocks of pine or hard wood. No attempt should be made to carve the inside of the boxes to shape until the joint has been accurately formed, only enough work being done on the inside to enable the stock to be brought into place along the joint.

11. In making core boxes for the body of globe valves, it is sometimes best to make models of the required cores out of plaster of Paris or wood and then cut these models on different lines so as to obtain sections, or to make templets by simply projecting sections of the boxes upon a drawing. After the insides of the boxes have been carefully worked out to templets made from drawings, or to a model that has been prepared, castings are made from the patterns and fitted together with dowel-pins.

A projection of the upper part *d*, Fig. 5 (*a*), of the box for the core shown at *a*, Fig. 4 (*g*), is shown in Fig. 5 (*b*). It will be noticed that in Fig. 5 the halves of the patterns are joined together by dowel-pins *h*. After the castings for the core box have been made and fitted together, test cores are made from plaster of Paris or lead, put together, and located in the mold to see that the core gives the required thickness of metal. If it does not, the box is changed until it is right, or the pattern is changed and a new box cast. Frequently, cores are made in a new core box, placed in a mold and a casting made, from which sections are cut to see that the metal is of the desired thickness.

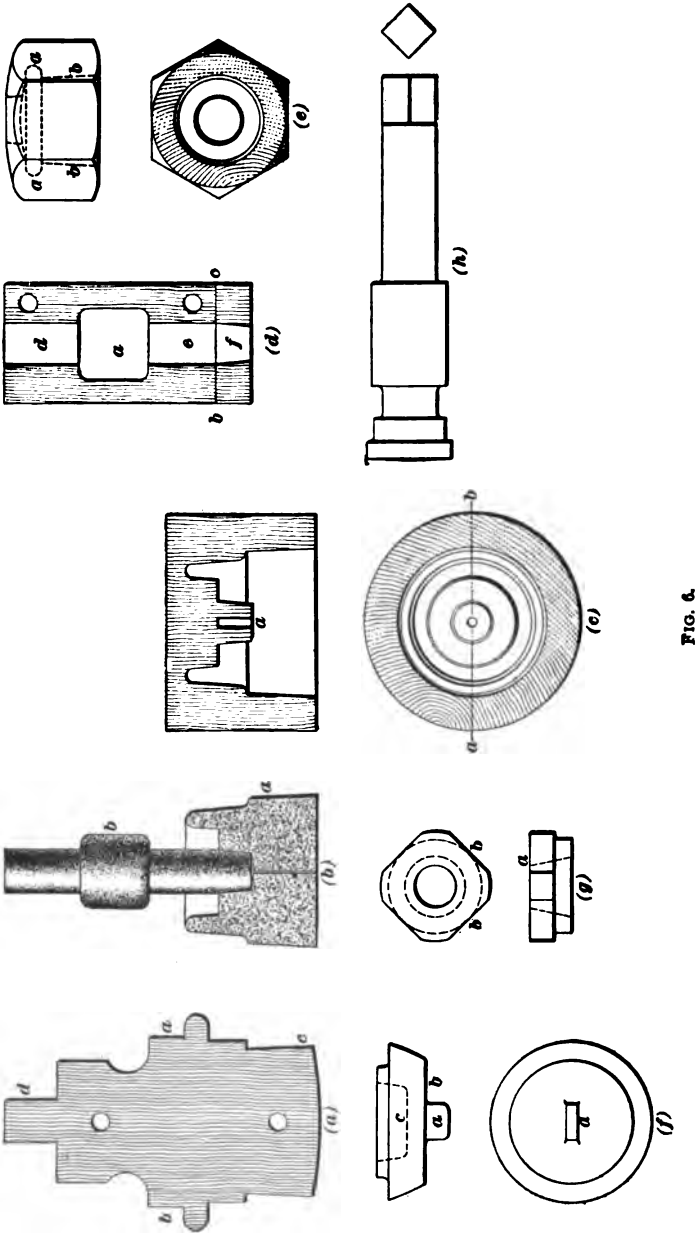


FIG. 6.

12. Manufacturers of valves spare no expense in making these metal core boxes and are very careful to get them correct, because of the large number of valves made. The core box for the core *b*, Fig. 4 (*g*), is shown at Fig. 5 (*d*), Fig. 5 (*c*) being a projection of the lower portion. It will be noticed that the core box shown in the two views (*a*) and (*b*), Fig. 5, has only one opening through which the core material can be introduced, this opening being at the end *a*, while the core box shown in Fig. 5 (*c*) and (*d*) has three openings, one at the end *c*, one at *d*, and another at *e*.

13. Pattern for the Valve Bonnet.—The pattern for the valve bonnet *b*, Fig. 4 (*a*), may be made as shown in Fig. 6 (*a*), which illustrates one-half of the pattern. In order to make the pattern, two pieces of pine should be jointed and doweled together in the ordinary way and the pattern turned to the form shown, necessary allowance being made for finish. After the pattern is turned, the core print should be varnished and the hexagonal portion *a b* given the required form, using the tool described in Art. **5.** The large core print *c* is turned a little larger on the end than where it joins the pattern, for reasons that will be described later. The small core print *d* is turned parallel.

14. Core Boxes for Valve Bonnet.—By referring to Fig. 4 (*a*), it will be noticed that the bonnet *b* has a rather complicated core, the portion *c* being cored out for clearance, while finish will be required at *d* to form the bearing for the valve stem *a*, and at *e* for the thread, the lower portion *f* being cored out both for clearance and lightness. In order to produce this complicated series of openings, two cores are necessary. These are illustrated in Fig. 6 (*b*), the larger core *a* being represented in section, and the smaller core *b*, solid. When similar cores are made larger, the smaller one should be arranged to go through the larger one, so as to give it better support, but for small work, such as is here illustrated, the method shown will give sufficient strength.

15. The core box for the larger core is shown in Fig. 6 (*c*). This may be turned up on a screw chuck from a single piece of wood, the grain running in the direction shown in the illustration. The reason for making the large print *c*, Fig. 6 (*a*), on the pattern tapered is that this box must be given draft on the inside, to allow the removal of the core. The small print *a*, Fig. 6 (*c*), is to receive the end of the small core, as shown in Fig. 6 (*b*). When making a core from these boxes, a nail or wire should be inserted into the hole in the end of the print *a*. When the core is rammed up, this nail is withdrawn, leaving a hole through the core, as shown in Fig. 6 (*b*).

Owing to the small size of the core *b*, Fig. 6 (*b*), it is well to make both halves of the box, for, if such small half cores were pasted together, they would not be as strong as the solid core. Fig. 6 (*d*) illustrates one-half of the necessary core box. The chamber *a* may be cut out with a carving gouge, or a box may be made in several pieces and each worked or turned out by itself. It is customary to make the box of at least two pieces, dividing it on the line *b c* so that the straight portions *d* and *e* can be worked out parallel and the tapered portion *f* turned out by itself.

16. Patterns for Small Details of the Valves.— The pattern for the packing nut can be made as shown in Fig. 6 (*e*), which gives both a plan and an elevation of the nut. This pattern can be made to leave its own core by turning it out on the inside, as indicated by the straight dotted lines *b* in the upper view, the recess *a a* being omitted. In such a pattern as this, the grain is usually allowed to run lengthwise of the nut, the end grain being shown in the lower view. To make this pattern, a piece of wood is placed on a screw chuck and the outside turned to a diameter sufficient to allow the hexagon to be formed. Sometimes, a more elaborate solid pattern is made for the nut and a separate core box used. This is always done when it is desired to core out a clearance at the upper end of the nut, as shown by the dotted lines at *a*, Fig. 6 (*e*).

17. The patterns for the valve and valve nut may be turned from one piece of wood, the wood being screwed on to a small face plate or screw chuck, and the valve pattern, Fig. 6 (*f*), is turned as shown in the illustration, with the exception of the portion marked *a*. In turning, the face *b* should be toward the chuck, so as to enable the pattern-maker to turn out the recess *c*. After the pattern is turned nearly off, it should be smoothed and varnished and then cut off. The rectangular projection *a* is fastened on afterwards, it being intended for the use of the machinist while grinding in the valve. After the valve has been cut off, the nut, Fig. 6 (*g*), can be turned, the face *a* being nearest the chuck during the turning. After the piece has been turned, smoothed, varnished, and cut off, the flats *b* for the wrench may be formed with a plane or chisel. The valve spindle, Fig. 6 (*h*), can be turned from one piece as shown. Patterns of small diameter like the valve spindle are not usually made in halves, because they would be too weak, and liable to break.

18. Where a large number of castings are to be made, it is very common practice to make such pieces as the valve nut and valve spindle in halves and to place them upon a card or a match board. At other times, the patterns are all made solid and a match, or odd side, is made from plaster or oiled sand, separate places being made to receive each pattern.

PATTERNS AND CORE BOXES FOR THREE-WAY COCK.

19. General Consideration of the Valve.—Before attempting to make the patterns for this valve, it is well to look somewhat into its characteristics. In Fig. 7 (*a*) is shown a plan of the top of the valve, and in Fig. 7 (*c*) is shown a front view, while Fig. 7 (*b*) shows a section of the valve on the line *A B*. It will be noticed that there are stops *s*, *s'* on the casting, against which the pin *a* on the plug or

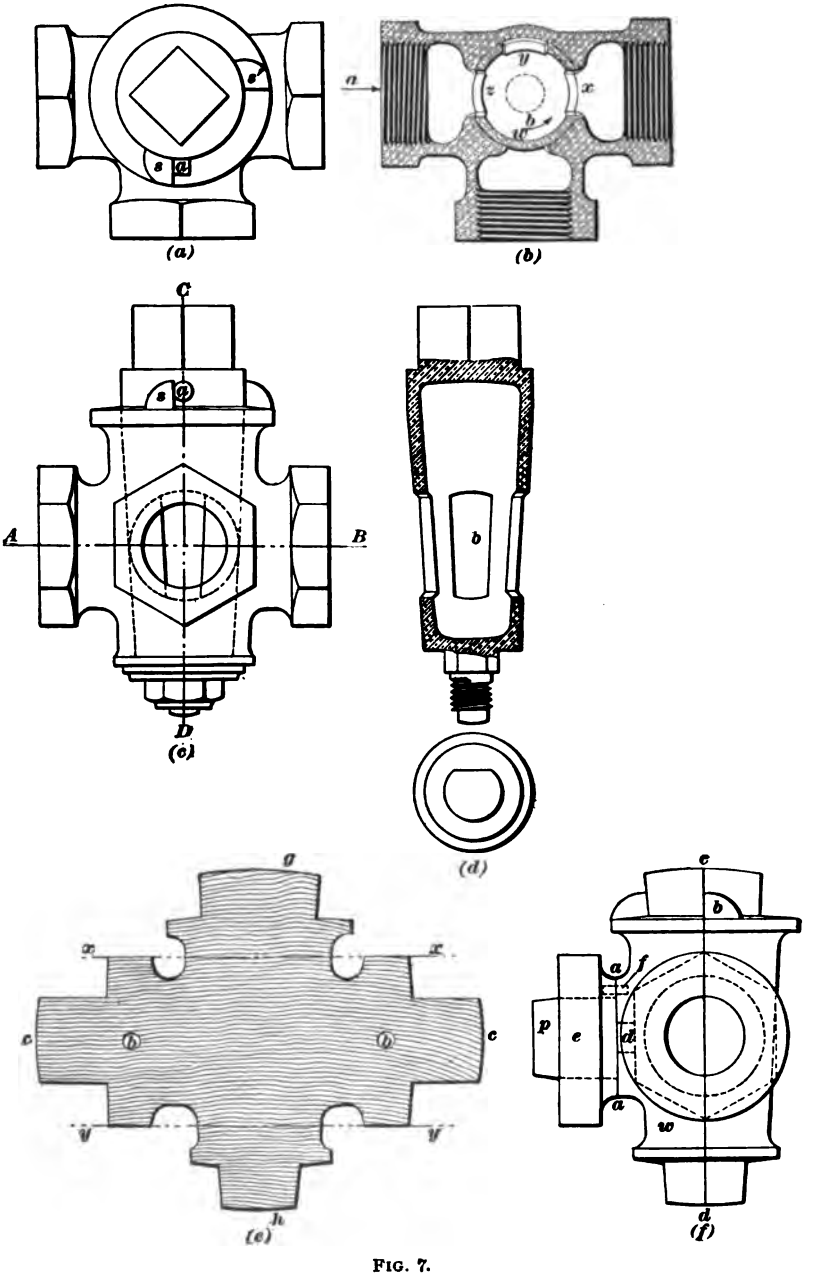


FIG. 7.

valve comes to rest. These stops are so placed that the plug cannot make more than a quarter of a revolution. The construction and operation of the valve can be best understood by referring to the sectional view shown in Fig. 7 (*b*). As shown in this illustration, the plug is in such a position that the openings *x* and *z* are in line with the straight portion of the body, so that water or steam entering at *a* passes straight through the cock. By turning the plug one-fourth of a revolution, as indicated by the arrow *b*, the opening *x* will come to the position *y*, the opening *y* will come to the position *z*, and the opening *z* to the position *w*, thus turning the flow at right angles and out through the side of the cock at *w*.

20. In making patterns and core boxes for this cock, the necessary allowance for shake, shrinkage, and finish must be made in each case. The outside of the main body of the pattern and much of the inside will require no finish, and, also, in many cases, the hexagonal parts are cast to their finished size; but the portions that have to be threaded and the portion of the body that is to receive the plug must be provided with sufficient stock for finishing.

21. Pattern for Valve.—The pattern for the valve is made in two parts, with a third part fitted to one side, as shown in Fig. 7 (*f*). One half of the pattern is shown in Fig. 7 (*c*). The pattern is parted on the line *c d*, and the hexagonal side piece *e*, with its fillet, is made separate from the body of the pattern, the division being made along the line *a a*. This piece *e* has a hole turned through it that fits over the core print *p*.

To make this valve pattern, two pieces of stock of sufficient size to make the piece shown in Fig. 7 (*e*) must be gotten out. These pieces are jointed and doweled together, the dowels being located at *b* and *b*, as shown in Fig. 7 (*e*). The pieces of stock may be gotten out somewhat longer in each direction than the pattern, and secured together by glue at the ends, or they may be glued together with paper between them.

If it is intended to make the body of the pattern without fastening on separate pieces, all the work cannot be done by turning, but a portion of it will have to be done with gouges and chisels after the turning is completed. Before turning, two lines should be laid off on the block at right angles to each other. These will correspond to the center lines *A B* and *C D*, Fig. 7 (*c*). A portion of the pattern along the line *A B* may be turned first. While in this position, only the core prints and the pieces from which the hexagonal ends are formed, together with their fillets, can be turned. When this operation is completed, the pattern is placed in the lathe at right angles to its former position and the other two core prints, and the part of the pattern outside of the dotted lines *x x* and *y y* is turned. It should be noticed that the core prints *g* and *h* are turned tapered and that the taper of the two prints is in line; that is, their outside surfaces will form a portion of the surface of a cone. The reasons for this will be explained later.

22. After the pattern is turned, the portion of the body that could not be finished in the lathe is formed by means of chisels and gouges, but, before proceeding with this work, it is best to true up the surface *a a*, planing it off parallel to the joint of the pattern along the line *c d* and allowing the proper distance between these two faces. After the surface *a a* has been planed, a circle is struck on it with a diameter equal to the distance *a a*. The body of the valve is then carved to the desired shape. The print *p* is shown by the dotted lines as extending to the surface *a a*. This print is turned with the small pin *d* on the end, which is glued into a hole drilled in the surface *a a*. The loose piece to form the hexagonal flange *c* can be turned up with a hole in it that will just fit over the core print. This piece is kept in its proper relation to the body of the pattern by means of the small dowel-pin *f*.

It will be noticed in Fig. 7 (*a*) and (*c*) that the stops *s* and *s'* are slightly removed from the center lines. If it is attempted to mold the stop *s'* in its proper position, the molder will

meet with considerable difficulty, but as the distance of the stop from the center line *C D* is only equal to half the diameter of the pin *a*, Fig. 7 (*c*), it is possible to place the stop on the pattern flush with the joint, as shown at *b*, Fig. 7 (*f*), the stop being filed back the desired distance after the casting is completed.

23. Method of Molding. — Before proceeding with the discussion of the core box, it may be well to notice the method of molding this pattern, as this has considerable bearing both on the construction of the pattern and on the core box. The portion of the pattern marked *w*, Fig. 7 (*f*), is supposed to go in the **cope,** or top part, of the mold and is shown there in Fig. 8 (*a*). In this illustration, the bottom part of the mold, or **drag,** has been omitted. The slab core *c* is shown as fitting over the core print *p'*. In the process of molding, before the slab core is placed in position, the pattern with the loose piece about the core print is placed in position and sand rammed up in the cope as far as the surface *p p*, flush with the top of the loose piece of the pattern. This sand is then struck off and the loose piece withdrawn, after which the slab core is placed over the core print, the surface resting on the surface of the sand *p p*. The ramming of the cope is then continued, care being taken not to strike the slab core while this is being done. This method may be pursued where only a comparatively small number of castings are to be made. When a large number of castings are being made, it is usual to provide the mold with an extra parting line; in other words, to mold the casting in a three-part flask. The slab core is made in a simple rectangular core box with one print in the bottom.

24. Core Box for Three-Way Cock.—One of the core boxes for the body of the three-way cock is shown in Fig. 8 (*b*). It will be noticed that the main portion of the core is tapered, and from this it will readily be seen why the core prints *g* and *h* in Fig. 7 (*c*) were tapered. By making these core prints tapered, and having this portion of

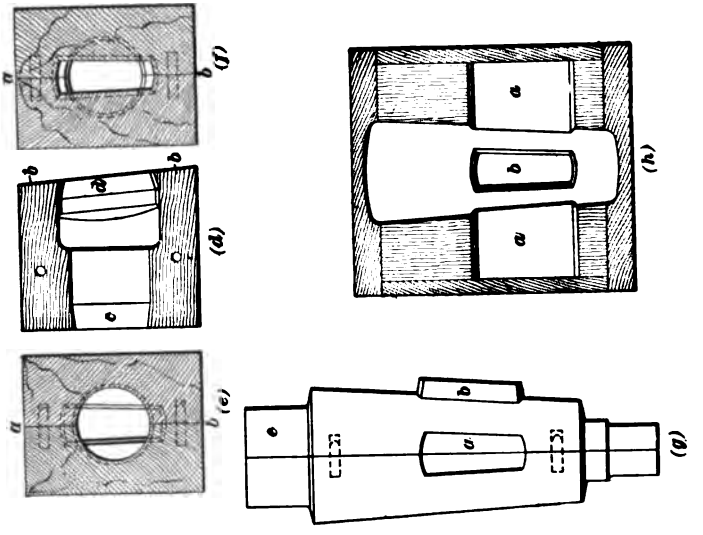
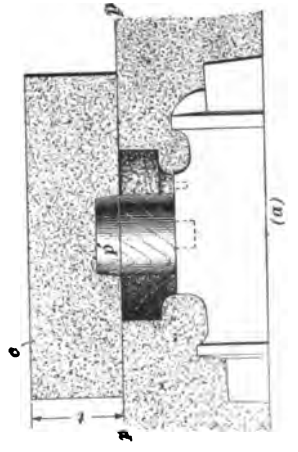
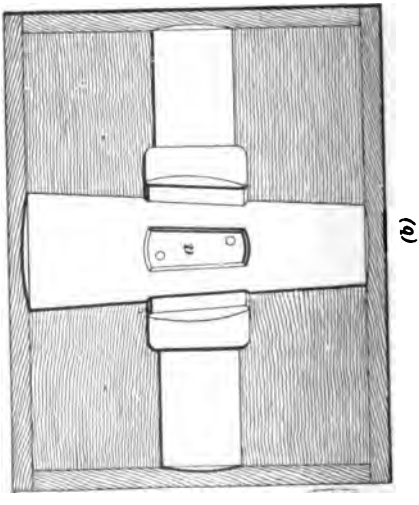


FIG. 8.





the core box formed as shown, it is much easier to work out the material to the desired form.

A one-half box is sufficient for this core, as both half cores are similar, the only difference being that one half core must be made without the print *a* shown in the box. The print *a* is, therefore, doweled on so that it may be removed and readily set in place again. This print is intended to receive the end of the side core that is made in the box shown in Fig. 8 (*d*).

The stock for this core box, Fig. 8 (*b*), must be thick enough to leave sufficient strength in the back after cutting away the material at the largest diameter. Four pieces are secured to the outside of the box, as shown, and clearance for draft on the ends of the core is cut from these pieces.

25. The core for the side opening is made separate. Fig. 8 (*d*), (*e*), and (*f*) shows three views of the box intended for this purpose. A complete box should be made for this core, the parting being on the line *a b*, and the two pieces doweled together, as shown. The end *b b*, Fig. 8 (*d*), must have the same taper as the plug part of the main box. The portion *d*, which is intended to form the projection that goes into the print left by the piece *a*, Fig. 8 (*b*), must be shaped to correspond with the print it is intended to fit, and the end *c* must be formed to correspond with the print *p* on the pattern Fig. 7 (*f*). The general construction of the box needs no comment, as it is similar to the core boxes already described.

26. Pattern for Plug.—The pattern for the plug is shown in Fig. 8 (*g*) and is made in halves, being parted diagonally across the square head, as shown. This pattern has three core prints, the two prints *a* on the parting line, and the print *b* on the side. The two prints *a* may be formed by letting in a piece of wood that will go directly across the pattern, the grain being at right angles to the main portion of the pattern. This is the strongest construction. The print *b* can be made of a separate piece of wood and be attached to the main portion of the pattern. On the square end *e* of

the pattern no allowance for finish will be required, but on the rest of the surface an allowance must be made.

27. Core Box for the Plug.—The manner of coring out the plug is shown in Fig. 7 (*d*). If a half box is made to serve for making the two halves of the cores, it will be necessary to fit a loose piece into the recess *b*, so that one-half of the core can be made without the projection that forms the side opening *b*, Fig. 7 (*d*). One point that must be observed in making the core and locating the core prints for the plug, is that the core is supported by the prints *a*, *a*, Fig. 8 (*h*), and hence this portion of the core box and pattern must be made very carefully, so that the prints will make a good fit in the mold, for, if they do not, the plug is liable to be thin on one side and thick on the other.

PATTERNS FOR WHEELS AND GEARS.

28. Wheels or Gears Having a Web or Plate in Place of Arms. — When the diameter of wheels is not great, as, for instance, in the case of small gears or pinions, a plate or web takes the place of a series of arms. In case the pattern is divided into two parts, the web, if thin, may be placed entirely on one part, the other half of the rim and the hub being made loose, or each half of the pattern may be made with one-half of the web. In either case, the stock for the web can be joined up as shown in Fig. 9. When the web is composed of six parts, as shown in Fig. 9, these parts may be sawed out from the board or plank, as shown at *a*. The

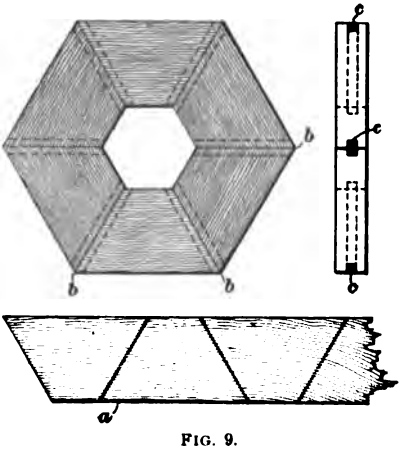


FIG. 9.

ends of the pieces should be finished on a trimmer and shoot board, so as to make perfect joints at *b*, *b*.

29. In order to strengthen these joints, a tongue *c* should be introduced into each joint. These tongues should be made of hard wood with the grain running at 45° to the joints. Any number of pieces can be gotten out in a manner similar to that shown at *a*. After the pieces are glued together, as shown, they may be sawed to approximately the required diameter with a band saw, and the courses, or segments for the rim, built up on the disk. It is usually unnecessary to have the pieces extend to the center, as the hub will cover this central opening, although there are times when it becomes necessary to make a solid web without the hole in the center. In such a case, it is easier to leave a small opening at the center and stop it by gluing in a separate piece.

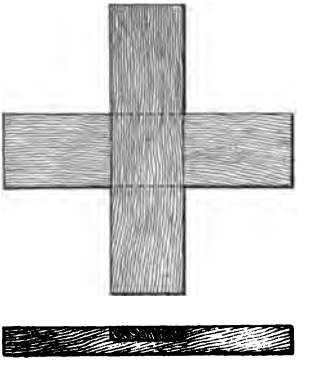


FIG. 10.

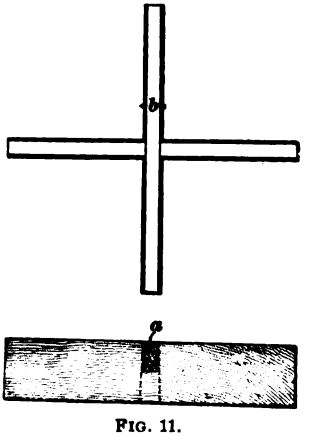


FIG. 11.

30. Wheel Patterns Having Four Arms.—When four arms are required, they are usually half checked together when the thickness at the center will permit doing so. Figs. 10 and 11 illustrate two methods of checking together two forms of arms. In Fig. 10 the arms are broad and flat and the pieces are simply checked together. In Fig. 11, the required arms are of considerable depth, and hence must have considerable draft. It will therefore be necessary to make the joint between them at *a* equal to the width *b* of the narrowest side of the arm.

31. Wheel Patterns With Six or More Arms.—When six or more arms are required, they may be joined together as shown in Fig. 12. When this method is employed, the pieces are prepared as shown at Fig. 12 (*a*), each piece being wide enough to form the round corners of the arm near the hub and rim, and long enough to allow the ends of the arms to be built into the rim of the wheel. The pieces are joined together with tongues, as shown, the joints at the center being made by means of a trimmer and shoot board. The outline of the finished arms is shown in the dotted lines, Fig. 12 (*b*), and the hub is shown in Fig. 12 (*b*) and (*c*).

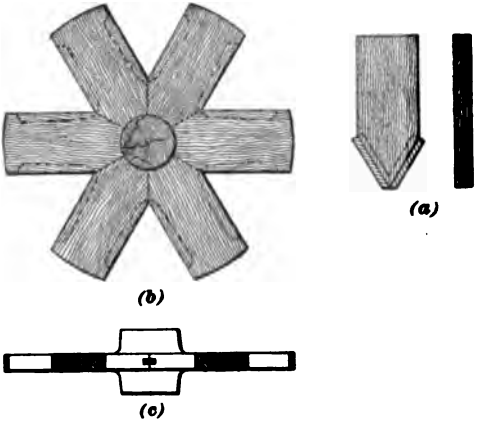


FIG. 12.

32. When the stock of the arms is thick enough to allow it, the method of joining shown in Fig. 13 may be employed. In this case, the joint is made as follows: The stock for the arms is dressed to the required width and thickness and a line made lengthwise on the center of both faces of each piece with a gauge. At the middle of the line on one side of the pieces shown in Fig. 13 (*a*) and (*c*), and at the middle of the line on both sides of the piece shown in Fig. 13 (*b*), a circle equal

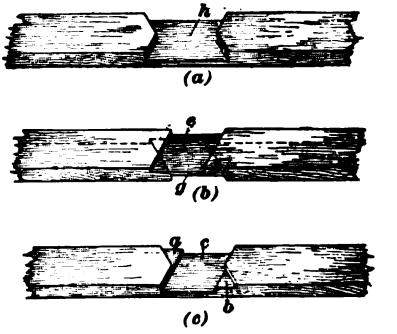


FIG. 13.

to the width of the piece is struck with a pair of dividers. In the case of six arms, a bevel is set to 60° and one set of lines laid off tangent to the circle and, in the case of (*a*) and (*c*), the bevel is then reversed and two other lines are laid off on the same side, which will cross the first ones at the center. The piece shown in Fig. 13 (*b*) is marked in the same way, except that instead of the four lines being on one side, two are on one side and two on the other, as shown. The gauge is now set to one-third the thickness of the stock and marks made along the edges of the arms. The pieces shown in Fig. 13 (*b*) and (*c*) are gauged from both sides, while the one shown in Fig. 13 (*a*) is gauged from one side only.

The first operation of checking is carried out as follows: The piece shown in Fig. 13 (*a*) is checked on both lines to two-thirds its depth in the first operation. The piece shown in Fig. 13 (*b*) is checked on alternate sides to one-third its depth, as shown, while in the case of the piece shown in Fig. 13 (*c*), the checking is carried out in two operations. In the first operation, the checking extends to one-third the depth, so as to obtain the surfaces *a* and *b*, which shall be equal in depth to the check shown at *e*, Fig. 13 (*b*). After this portion of the material has been removed, the stock is checked along the other two lines to the gauge lines representing two-thirds the thickness of the stock, so as to obtain the surface *c*.

If these three pieces have been accurately cut as described, they will fit together so as to form six arms. Before gluing the pieces together, care should be taken to see that the joints do not fit too tightly, as this may distort the arms, tending to bend them out of the plane in which they belong.

PATTERN FOR SHAFT COUPLING.

33. General Consideration of Casting Required. The finished casting is shown in Fig. 14 (*a*) and (*b*). This casting is to be finished all over, with the exception of the recess *a*, and hence stock must be allowed on all surfaces to be finished both inside and outside. No allowance is

made for the bolt holes *b*, as these will be drilled subsequently through the solid metal.

34. Construction of the Pattern. — Fig. 14 (*c*) shows a section of the pattern, and Fig. 14 (*d*) a projection. It will be noticed that the disk is built up of two layers, or courses, *a* and *b*, the courses being joined together like those shown in Fig. 9, except that the tongues are omitted. These tongues are unnecessary in this case, because the two

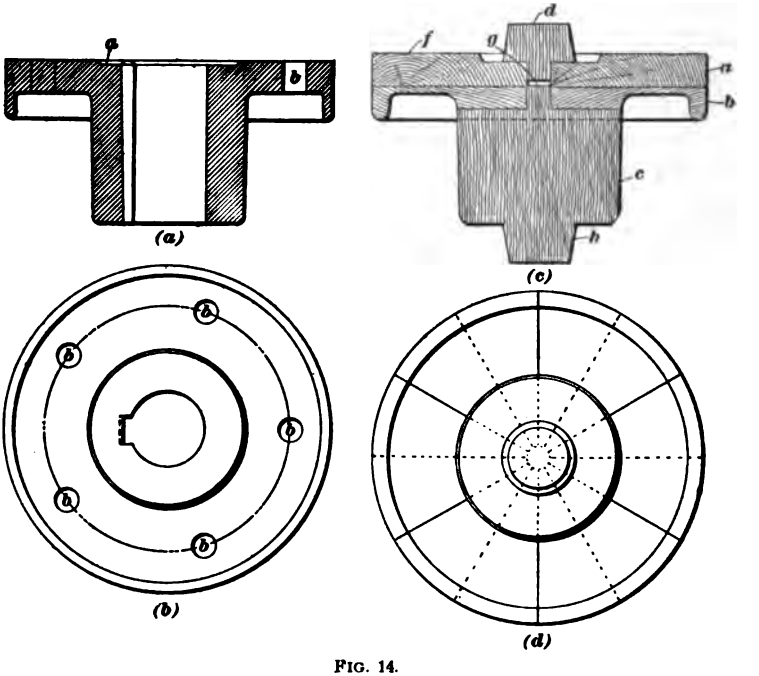


FIG. 14.

courses are arranged so as to break joints, as indicated by the dotted lines in Fig. 14 (*d*). The hub *c* and the core print *d* are turned separately, with pins on them to fit the hole *g* in the disk, thus making it easy to have them concentric with the outer circle of the coupling. The core print *d* should remain loose so that it may be removed for laying the pattern flat on the board in the first operation of molding.

The hub is glued in place. In this pattern, draft is allowed on all surfaces from the face *f*. The core print *h* is turned with the hub *c*.

PATTERNS FOR CYLINDER HEAD AND COVER.

35. Construction of Cylinder Head.—The cylinder-head cover chosen to illustrate this style of pattern is shown at Fig. 15 (*a*) and (*b*), the cylinder head being intended for

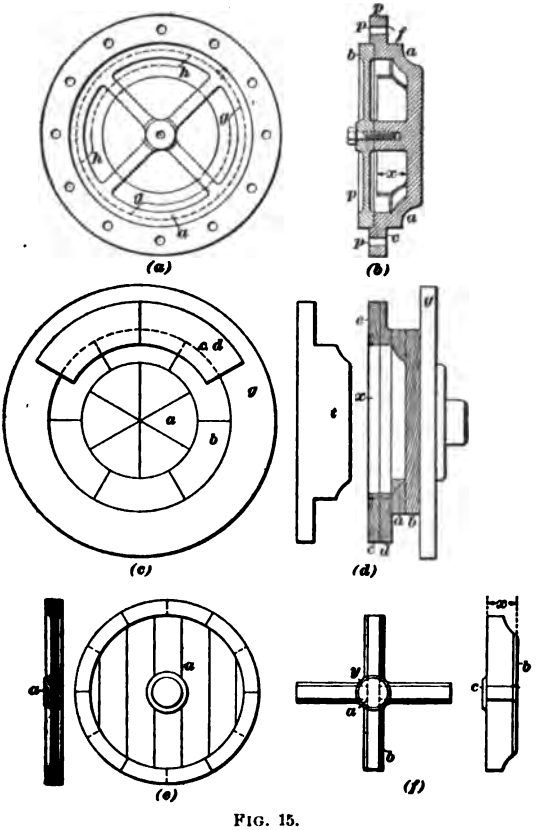


FIG. 15.

a Corliss engine. Fig. 15 (*b*) shows a section of the head with the cover *b* in place. This same head may also be used

for a slide-valve engine by filling up on the pattern one of the spaces marked *a*. These spaces are also shown by dotted lines in Fig. 15 (*a*).

36. Pattern for Cylinder Head.—Having selected dry lumber, proceed to build the pattern for the cylinder head as shown in Fig. 15 (*c*) and (*d*), remembering to allow stock for turning or finishing where the marks *f* and *p* appear on the drawing, Fig. 15 (*b*), *f* standing for finish and *p* for polish.

Before proceeding to build the pattern, a full-sized section of the head should be drawn in order to determine the thickness and number of courses needed. This drawing will also give the width of the courses necessary. In the case in hand, four courses have been selected, as shown at *a*, *b*, *c*, and *d*, Fig. 15 (*d*). After planing the lumber to an even thickness, and sawing out the segments for each course, it is well to stack them up crosswise and let them stand for several days in a dry place to season more fully.

37. In order to build up the pattern, a wooden face plate must be prepared, as shown at *g*, Fig. 15 (*c*) and (*d*). After this face plate has been built up and faced off in the lathe, the successive series of segments are built upon it, each segment being faced off in the lathe after it is in place, so as to insure a perfect bearing for the succeeding segment. After all the courses have been built up, a templet should be cut out, as shown at *t*, Fig. 15 (*d*). This templet may be made out of a board $\frac{1}{8}$ inch to $\frac{1}{4}$ inch thick, with the edges somewhat sharpened, or a thin sheet of metal, and the shape should be the same as the cross-section of the inside of the cylinder head. The small step on the face of the cylinder head, intended to receive the cover, should not be provided for in the pattern, as this can easily be turned in afterwards by the machinist. The inside of the pattern is turned out to correspond with the templet *t* and the outside of the segments *c* and *d* turned to the proper diameter, after which the pattern should be taken off from the face plate and the face *e* screwed to the face plate so as to

permit the back side of the pattern to be turned. Care must be taken to center the outside of the segments *c* and *d* accurately. It will be seen by the dotted lines in Fig. 15 (*a*) that the grooves *a* do not extend entirely around the pattern, but in turning they are turned all the way around and the portion *g h*, Fig. 15 (*a*), is subsequently filled in.

38. After the pattern is turned, the ribs and the hub in the center must be made. The stock for the ribs is checked together as shown at *a*, Fig. 15 (*f*). Before half checking the pieces together, it may be well to roughly cut the ends to fit the templet *t*, after which care must be taken to see that, in half checking the pieces, they are joined exactly in the center, so that when the ribs are located as shown in Fig. 15 (*a*), the small boss will be exactly concentric with the head. The ribs should have a little taper to allow for draft, and should be made of such a height that the dimension *x*, in Fig. 15 (*b*), will correspond with that shown in Fig. 15 (*f*). Instead of gluing fillets into the corners at the base of the ribs after the latter are fastened in place, it is better to glue the fillets to the ribs, as shown in Fig. 15 (*f*). The hub at the center should also be formed by gluing corner pieces into the corners of the ribs, as shown, and turning a small hub to go on top of the pattern, as shown at *c*, Fig. 15 (*f*). After the ribs are completed, they are placed in the pattern, glued in position, and the fillets at the ends of the ribs made and glued into place.

39. Pattern for Cover.—The pattern for the false cover of the head is made as shown in plan and section in Fig. 15 (*e*). The plate is made of strips to prevent it from warping, and if the joints are not glued, the danger of the pattern cracking is greatly reduced. The strips are held together by two courses of segments, one on each side, as shown in the cross-section. Two small bosses *a* are turned and located in the center of the plate, as shown. The pieces for this pattern are gotten out in the usual manner and turned to proper form upon a wooden face plate. In the case of large engines, when very thin false covers are used, it is

sometimes necessary to make the wooden pattern very carefully and to make a supporting form for it; then make one casting from this and finish it carefully so that it may be used as an iron pattern for all future castings that may be required. It is usually best to do this in the case of all large, thin castings. The supporting form for the wooden pattern may be so constructed as to fill all the space beneath the pattern, or it may be a frame supporting the pattern at frequent intervals.

PATTERN FOR CRANK DISK.

40. General Consideration of Casting Required. In Fig. 16 (*a*) is shown an elevation and two sections of a crank disk, one section being taken on the line *C D* and the other on the line *A B*. It will be noticed that the crank is provided with a counterbalance *d*, which is placed opposite the hub *e* for the crankpin. This hub *e* on small disks would be cast solid and the hole in it subsequently drilled and bored. The hub for the shaft *h* would always be cast with the hole cored through it.

41. Construction of Pattern for Crank Disk. The general construction of the pattern for this disk is shown in Fig. 16 (*b*), (*c*), and (*d*). The main web of the crank is composed of narrow boards, as shown in the elevation and section, Fig. 16 (*b*). These narrow strips *a* should not be glued together along their joints, but should be held in place by the segments *b* and *c* of which the rim is built up. After having built up the courses or segments of the plate, they should be allowed to dry for some time before turning, and, while this is going on, the counterbalance, hub, and crankpin hub may be made. It will be noticed in the sections shown in Fig. 16 (*a*) that the hubs project on one side of the crank. It is more convenient to make the projecting portion of the hubs separate, and hence the first pieces for the hubs are turned to the same thickness as the counterbalance, as shown at *a*, Fig. 16 (*c*).

After the hub is turned, one side is sawed off flat, as shown at x. This is a better way than fitting the counterbalance around the hub. The counterbalance is then carved out with its fillet in place and glued to the hub. After the hub and the counterbalance are fitted together as shown in Fig. 16 (c), the projecting portion of the hub is turned up, together with its core print, as shown in Fig. 16 (d). The hub e for the crankpin, Fig. 16 (a), is also turned up. The rib i, Fig. 16 (a), for connecting the shaft and crankpin hubs, need not be gotten out until it is necessary to attach the parts to the pattern. The portion of the hub e projecting beyond the rim of the pattern should also be made detachable and secured by dowel-pins. By the time these parts are completed, the segments for the main portion of the disk will be dry and this portion can

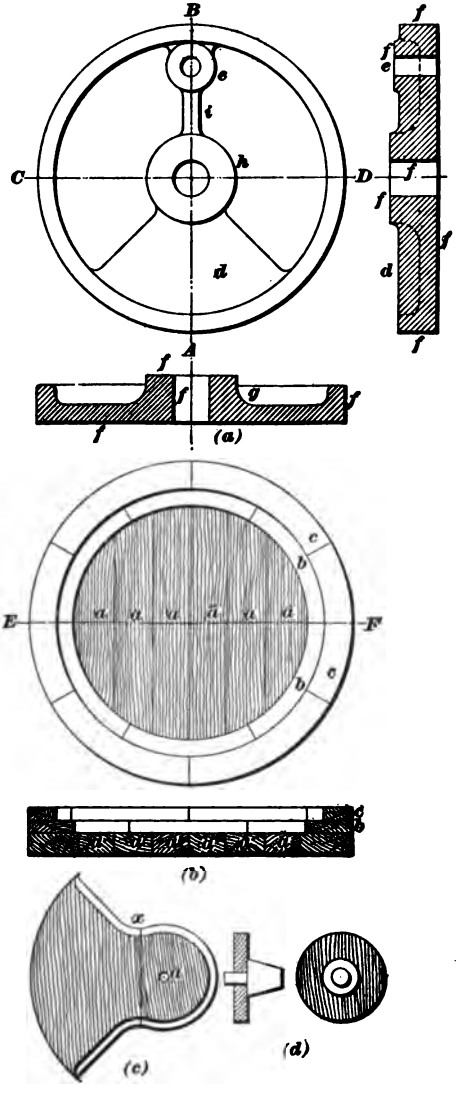


FIG. 16.

be screwed to the face plate of a lathe and turned up. In turning, the diameter should be made smaller on the plain side of the pattern for draft. The crank is molded in the position shown in the lower section, Fig. 16 (*a*), that is, with the hub up. The casting is made with this side up because the plain surface must be free from scum and dirt, in order that it may have a good smooth surface when machined.

42. Allowance for finish must be made on all the surfaces that are marked *f* in Fig. 16 (*a*). After the main portion of the disk is turned, the separate pieces are secured to it, care being taken to see that the grain in these portions runs in the same direction as the grain in the strips forming the web of the disk, as this will allow the parts to shrink uniformly. After the hub *h*, counterbalance *d*, and crankpin hub *e*, Fig. 16 (*a*), are in place, the web *i* and the fillets between the hub *e* and the outside of the disk are formed and glued in place. The reason for making the projecting portions of both hubs detachable is that this surface of the pattern may be placed in contact with the molding board during the first operation of molding.

PATTERN FOR STEAM-CHEST COVER.

43. General Consideration.—A steam-chest cover for a slide-valve engine is shown in Fig. 17 (*a*), the upper view being an elevation, and the lower one a section on the line *A B*. This cover is strengthened by cross-ribs in order to enable it to withstand the steam pressure to which it will be subjected. This is a very simple casting for which to make a pattern, and there are a number of ways in which it can be made. If it is desired to make it quickly, and make but one casting from it, a square piece of board with ribs and strips nailed on the outer edges will answer the purpose, but this will not do for a pattern in frequent use, because it will probably split and warp out of shape. When the pattern is intended for continuous use, it is better to build it up of separate pieces.

44. Construction of a Pattern for Steam-Chest Cover.—Fig. 17 (*b*) shows two views of a partially completed pattern for a steam-chest cover, the upper one being an elevation and the lower one a section. The central part, or web, is made up of narrow strips, as in the case of the pattern of the disk crank. These strips are fitted into a groove in the outer frame surrounding them. It will be noticed that this frame is mitered at the corners and joined together by tongues, as indicated by the dotted lines at *a*. The pattern is molded and the casting poured with the side that is to go next to the cylinder, down, that is, the side *c*, Fig. 17 (*a*). This is done to insure clean iron on this surface, because it is to be planed. Stock must be left to allow for finish on all the surfaces marked *f*, Fig. 17 (*a*). The four corners of the pattern are rounded, as indicated by the dotted lines, Fig. 17 (*b*), after which the cross-ribs are made by joining two pieces together at the center and cutting them to the desired form. These ribs should be doweled to the cover so that they may be taken off to allow the molder to lay the pattern flat on the board during the first operation in molding. The construction of the ribs is very simple, and hence they are not shown in the illustration.

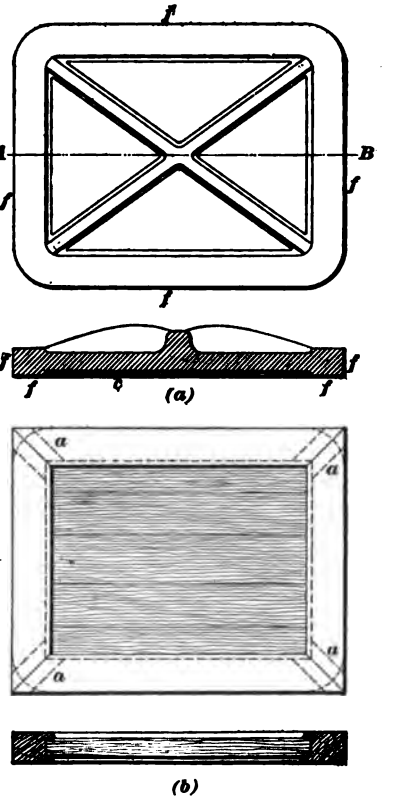


FIG. 17.

PATTERNS FOR CORLISS ENGINE VALVE-GEAR DETAILS.

45. General Consideration of Castings.—Fig. 18 shows two views of a hook lever for a Corliss engine valve gear and Fig. 19 (*a*) shows two views of an exhaust arm for the Corliss engine. The two castings have very similar characteristics, that is, each is composed of one or more flat levers having an oval cross-section and bosses or hubs at the ends. The exhaust arm shown in Fig. 19 (*a*) is the simpler of the two, and hence its construction will be taken up first.

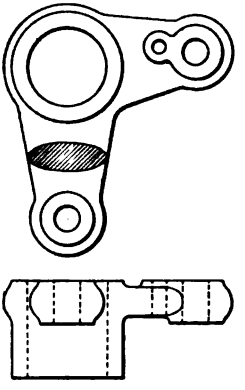


FIG. 18.

46. Pattern for Exhaust Arm. A piece of wood is planed parallel on its sides to the thickness *a*, Fig. 19 (*a*), and, after the outline of the arm is laid out upon it, it is carefully sawed out with a narrow band saw to the shape shown in Fig. 19 (*b*). After this, two $\frac{3}{4}$-inch holes are bored through the pattern, one at the center of each hub. Care should be taken to see that these holes are perpendicular to the surface of the block and parallel to each other, so that

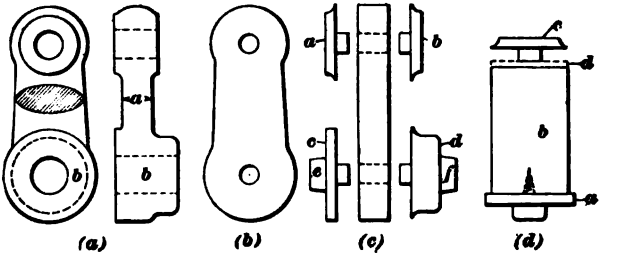


FIG. 19.

the distance from center to center shall be the same on both sides. After these holes have been bored, the four small bosses *a*, *b*, *c*, and *d*, Fig. 19 (*c*), are turned as shown.

These bosses are provided with pins that fit tightly into the holes bored in the arm. Owing to the fact that the larger end *b*, Fig. 19 (*a*), contains much more metal than the smaller end, it is necessary to make provision for cooling it as rapidly as possible, in order to prevent the smaller portion from drawing metal from it as it cools. This is accomplished by coring a hole through the larger end, the hole through the smaller end being drilled through the solid metal after the casting is completed. To provide for this core, two core prints *e* and *f* are provided on the bosses *c* and *d*, Fig. 19 (*c*).

47. To turn the bosses for this pattern, first saw out, from a thick plank, a rough piece large enough in diameter to turn the largest boss, and screw it to the screw chuck of the lathe, as shown in Fig. 19 (*d*), *a* being the screw chuck and *b* the block. In this way, the bosses may be turned and cut off with a narrow cutting-off chisel. One completed boss is shown at *c*, and the dotted lines at *d* represent the amount removed by the parting chisel. The grain in this piece should run crosswise and not in the direction of the center line of the boss, as the latter arrangement would make it difficult to turn the fillets without breaking their outer edges. When the bosses are completed, they are glued in place on each side of the arm, care being taken to locate them so that the grain of the wood in the bosses and the arm runs in the same direction. The arm is next worked to an oval shape between the bosses, as shown in Fig. 19 (*a*). The corners should be carved carefully to size. Sandpaper should be used only for the final finishing; it is not good practice to do with sandpaper what should be done with tools. As shown in the illustration, this pattern is made solid or without a parting line. When many castings are required, it is well to make a match of oil sand or plaster, or metal patterns may be made in halves.

48. Pattern for Hook Lever.—The pattern for the hook lever shown in Fig. 18 is made in the same manner as

that for the exhaust arm, except that the plate forming the two arms is made in two pieces and fastened together with a tongue, as shown in Fig. 20. In this case, the bosses will serve to hold the joint together when glued on each side.

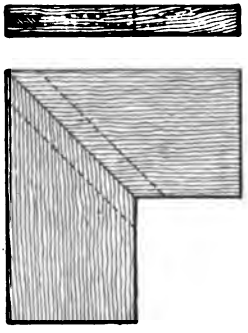


FIG. 20.

PATTERN FOR SLIDE-VALVE ENGINE CYLINDER.

49. Construction of Cylinder. Slide-valve engine cylinders are made in a variety of forms. The one chosen and explained here is of a well-known type and is illustrated by the three views shown in Fig. 21, (*a*) being a longitudinal section through the cylinder, steam chest, and ports, (*b*) a section on the line *A B* showing the

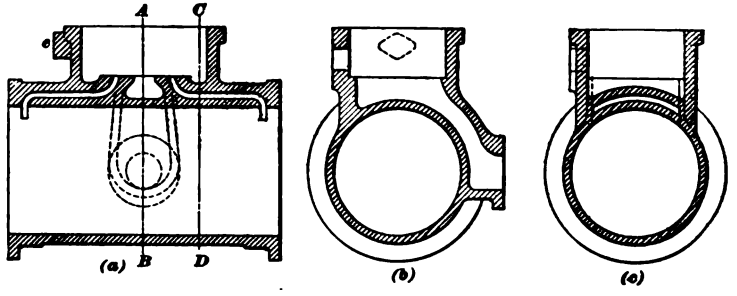


FIG. 21.

exhaust port, and (*c*) a section on the line *C D* showing the steam port and steam chest. From this it will be seen that quite a complicated system of coring is necessary.

50. Pattern for the Cylinder.—The making of the pattern for this cylinder depends largely on its size. When the diameter is to be less than 12 inches, the body may be built up solid, but, when above that size, it is better to build it with staves, as shown in Fig. 22. In this case, only one-half of the pattern is shown, as that is all that will be needed for explanation. This pattern is built up in a

as illustrated in Fig. 16, Part 2, the supports *a* being sawed out in the form of polygons to receive the staves *b*. Make the supports *a* of pieces so placed that the grain of the wood runs approximately in the direction of the circumference of the cylinder, as in Fig. 22 (*c*), for if made of single pieces, they will shrink across the grain and so reduce one diameter of the cylinder more than the other. The staves are so placed that the core prints at the ends of the pattern can be turned from them. To form the central portion of the pattern and to allow for the thickness of the cylinder, an extra thickness is glued on each stave from *c* to *d*, as shown in Fig. 22 (*a*). These extra pieces can also be seen

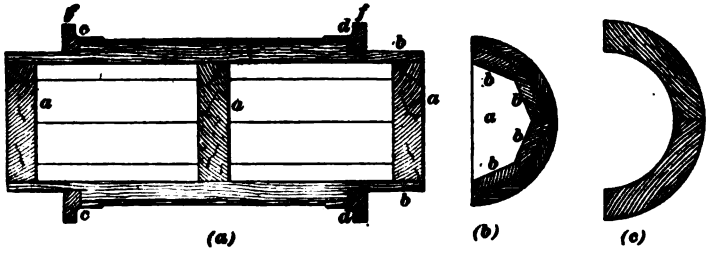


FIG. 22.

on top of the staves, Fig. 22 (*b*). This method makes a stronger pattern than can be formed by fastening the prints on the ends with screws or glue. The flanges *f* are made thick enough so that the fillets on the back can be turned from the stock of the flanges. The flanges should be made with the grain running diagonally, as shown in Fig. 22 (*c*), as this method of placing the wood will prevent the shrinkage from affecting the flanges to any great extent.

51. The cylinder body is built up and turned before the steam chest is made and fitted. The steam chest is then fitted on as shown in Fig. 23 (*a*) and (*b*). Only one half of the pattern will have to be fitted with the steam chest, the other half simply requiring one-half of the flange and core print for the exhaust port as shown at *h*. The pieces for the exhaust passage *g* and thickness *i* over the steam ports are shown in place; they must be carved out of

wood and glued and screwed to the pattern. The fillets at *a* and *b*, Fig. 23 (*a*), are cut out from solid blocks that are placed between the pieces *i* and the steam chest proper; this prevents all danger of the fillets coming out or being stripped from the pattern. The steam chest *s* may be made solid or built up as a box, the construction depending on its size. The strips *e* on the steam chest, which give extra

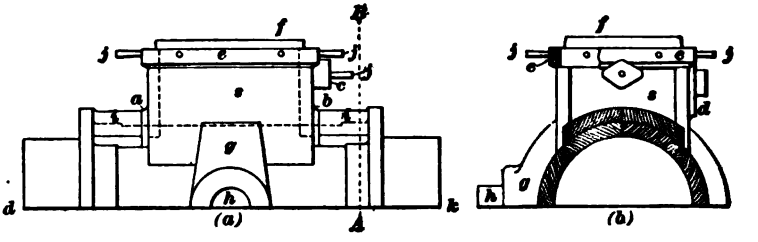


FIG. 23.

thickness of metal for the studs, are made loose, being held in place during molding by long dowel-pins *j*. Also, the valve-stem stuffingbox *c* and the facing *d* around the live-steam opening are loose and fastened in the same way. In Fig. 23 (*b*), a portion of the strip *e* has been broken away to show the manner of letting it into the pattern. This is to prevent its being moved out of place during ramming, after the dowel-pins have been taken out.

52. This pattern is to be molded in a two-part flask, parted on the line *dk*, all the loose pieces mentioned being made in sections and so placed that the main pattern will draw away and leave them in the sand; they can then be drawn into the opening left by the pattern and removed, one piece at a time. The core print *f* for the steam chest should be doweled on also; if made fast, the molder will probably tear it off, as it is a great convenience to have this print loose so that it can be placed back in the bottom of the mold while drawing the loose pieces and dressing up the mold.

53. Core Boxes for Cylinders.—The core boxes for the steam ports are shown in Fig. 24, (*a*) showing a side

view of the core box with the side *a*, Fig. 24 (*c*), removed. The core is swept up on the outside along the length marked *x*, a special sweep being provided for this purpose, which is guided by the sides *a* and *b*, Fig. 24 (*b*) and (*c*). The piece *c* is made to form the upper part of the core, because it changes from a circular shape to a straight part just where it enters the steam chest. Fig. 24 (*b*) is a top view and Fig. 24 (*c*) is an end view of the box with the end *d*, Fig. 24 (*a*), removed.

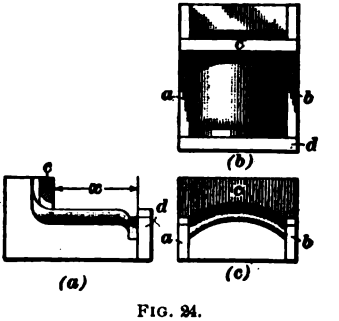


FIG. 24.

54. The exhaust-port core box is made in halves, and one half is shown in Fig. 25, the other half being like this, except that it is made left-handed, so that the two halves will fit when put together. The dotted line in Fig. 25 (*a*) shows how the passage is widened to maintain a constant area throughout, that is, it is cut down along the part of the passage occupied by the arrow in Fig. 25 (*b*).

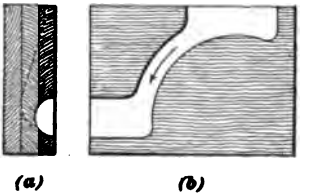


FIG. 25.

55. The core box for the steam chest may be made as shown in Fig. 26. In (*a*), the side of the box, and in (*b*), the end of the box, have been removed to show the inside. The piece *d*, which forms the valve face, is screwed to the bottom of the box and the sides fitted around it. The core prints *1*, *2*, and *3* are to receive the ends of the steam-port and exhaust-port cores. The steam-chest core is the first that is set in the mold, the cylinder being molded with the steam chest down. After this, the exhaust-port and steam-port cores are set with their ends in the openings left by the prints *1*, *2*, and *3*, Fig. 26. The core for the cylinder body is usually swept up on an iron cylinder wrapped with

hay rope, the prints to receive the ends of the steam-port cores being formed in the core. In the case of small cylinders, the prints for the end of the port cores, as shown at *1*, *2*, and *3*, Fig. 26, are frequently made of the form shown in Fig. 27 (*a*), and the cores for the steam ports are provided with projections to fill the space between the

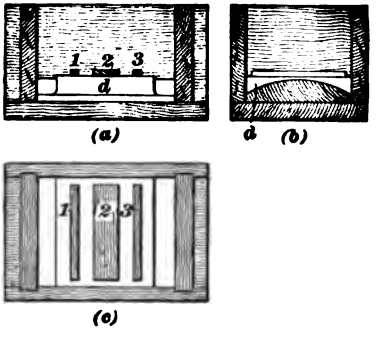


FIG. 26.

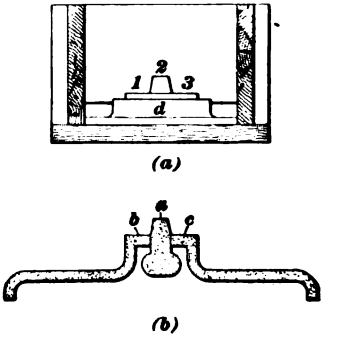


FIG. 27.

regular-port print and the exhaust-port print. The general form of the cores is shown by Fig. 27 (*b*), in which *a* is the exhaust-port core print and *b* and *c* the projections on the end of the steam-port cores. When this method is employed, the core box shown in Fig. 24 is made in such a manner as to provide for the projections on the cores as shown at *b* and *c*, Fig. 27 (*b*).

56. It is possible to get along by making only one-half of the cylinder pattern by making all the parts for the steam chest, port passages, etc., detachable, and arranging the pattern so that only the portion for the print *h*, Fig. 23, and the flange that surrounds it will be used in molding the second half. Of course, it will be necessary to place these on the opposite side of the pattern, so that the two halves will come together properly. When this is done, each half of the mold can be made separately and then put together. Patterns for Corliss engine cylinders may be constructed in a similar manner.

PATTERNMAKING.

(PART 4.)

PRACTICAL EXAMPLES OF PATTERN-MAKING.

STOP OR THROTTLE VALVE.

1. General Consideration of the Castings Required.—A **stop,** or **throttle, valve** is shown in section

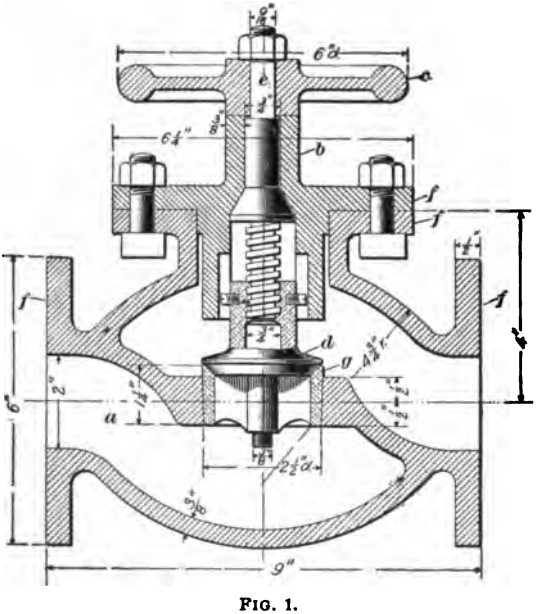


FIG. 1.

in Fig. 1. The body *a*, the bonnet *b*, and the hand wheel *c*

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are all made of cast iron, while the valve *d*, valve stem *e*, and seat *g* are made of brass. Finish must be allowed for all joints and for all faces marked *f*.

2. Pattern for Valve Body.—This throttle valve is similar to the ordinary globe valve shown in Fig. 4,

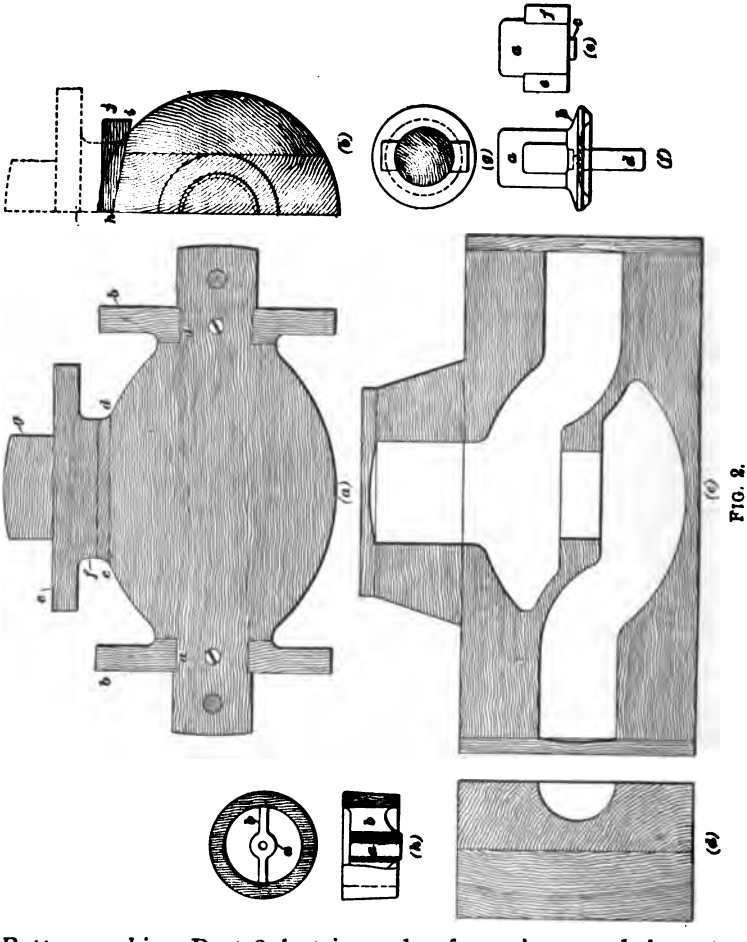

FIG. 2.

Patternmaking, Part 3, but is made of cast iron, and the patterns for it differ somewhat in construction from the globe-valve pattern. Fig. 2 (*a*) shows one-half of the pattern and

illustrates the method of joining the different parts. The stock for the main portion of the valve should be sawed out about 16 inches long, which will allow about 1¾ inches on each end for screwing the halves together while turning. The halves of this pattern should not be glued together, as they must be taken apart and put together again before the turning is finished. The end flanges fit in recesses formed in the core prints, as shown at *a*, Fig. 2 (*a*). The flanges *b*, Fig. 2 (*a*), are turned on the pattern, that is, they are first bored and faced to fit the recesses in the core prints, after which they are screwed and glued in place and then turned up or finished during the work of finishing the valve body. This insures their being concentric with the body of the pattern. The body should be turned to a templet cut to a 4¾-inch radius.

Owing to the fact that the body is oval and not round, the side flange *e*, together with the portion of the pattern connecting it to the body, has to be joined in a special manner. If a flat surface were formed on one side of the body of the pattern, it would have an oval outline; hence, the surface must be formed in such a manner as to have a circular outline. This is accomplished by cutting the faces of the halves of the pattern at an angle, as seen in the end view, Fig. 2 (*b*), which shows the pattern with the flange *b* removed. Two wedge-shaped blocks *j* are fitted to the pattern, being joined along the line *h i*, Fig. 2 (*b*), and along the line *c d*, Fig. 2 (*a*). Upon the back of these blocks *j*, the flange *e* and the portion *f* joining it to the pattern are secured, they having previously been turned. After this, the necessary fillets are worked out of the wedges *j*, Fig. 2 (*b*), the form of the half pattern when completed being indicated by the dotted lines. In the illustration, the core print *g* is represented as being simply glued and screwed to the flange *e*.

3. Core Box for Valve Body.—One-half of the core box for the valve body is shown in Fig. 2 (*c*) and an end view with the end board removed and the side projection

omitted is shown at Fig. 2 (*d*). From this it will be seen that the core box is built up from two or more flat pieces glued together. In the illustration, the separating bridge is shown as being carved out of the piece forming the core

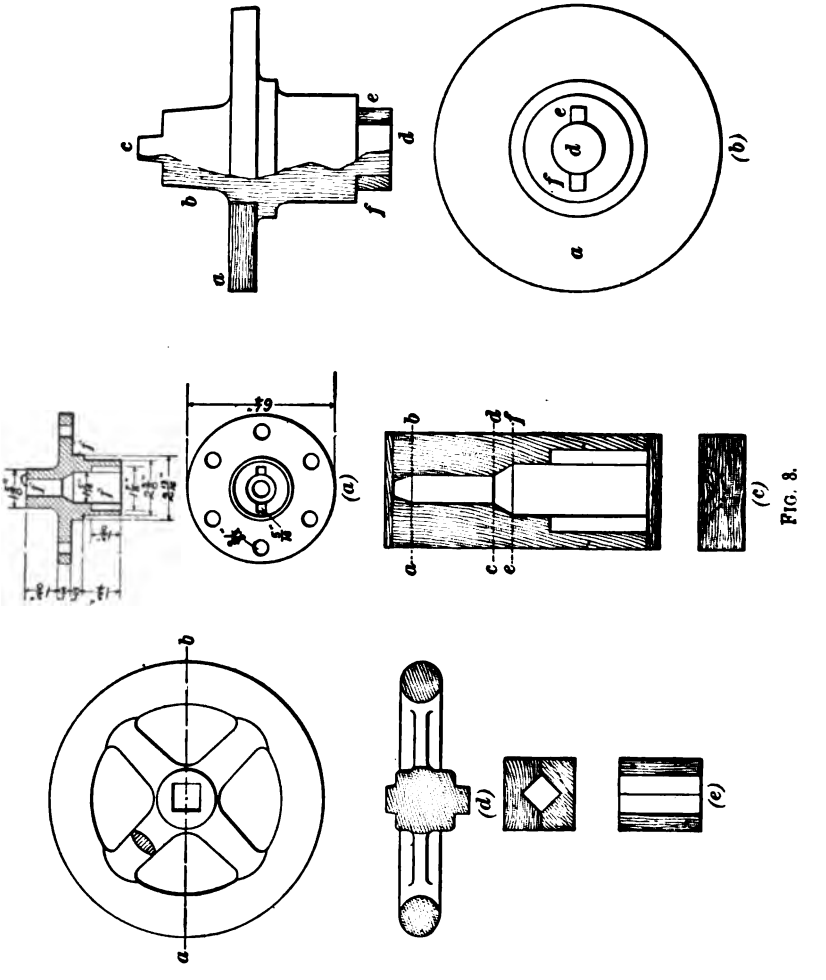

FIG. 8.

box. This bridge is cut down almost perpendicular to the surface of the box, very little draft being allowed on the sides and a small fillet being made at the bottom. It will

be seen that in order that the cores may match when pasted together, another half box is needed. One-half is, however, sometimes made to answer by making two separating bridges, one right-handed and one left-handed, which are doweled in place, so that, when the cores are being made, the bridges are used alternately. This apparently accomplishes the same purpose as two half-completed core boxes, but in practice it does not give the same satisfaction, as the bridges are liable to be broken, lost, or rammed out of place when making cores, resulting in an imperfect casting, and, as this kind of pattern is liable to be used constantly, it will be more serviceable to make two complete half boxes with bridges as represented. The ends and side of the box are closed with boards, as shown, the necessary draft being formed in these boards for the ends of the cores. For carving such a box, it will be necessary to make templets for the various cross-sections.

4. Bonnet Pattern.—A detail of the bonnet casting is shown in Fig. 3 (*a*) and the pattern is shown in plan and elevation at Fig. 3 (*b*). The upper view shows an elevation of the pattern, a portion of which has been broken away to illustrate the construction. The pattern is drawn to a larger scale than the casting. The flange *a* for the pattern is turned after it is fitted and fastened to the main portion of the pattern. As shown in the illustration, this pattern is not parted and is made to mold endwise. It will be necessary to have a molding board with a hole in the center for the portion *b* to project through during the first operation of molding. The main body of the pattern, including the core print *c* and the cylindrical portion of the print *d*, are turned from one piece. The auxiliary core prints *e* and *f* are glued and screwed in place.

5. Core Box for Bonnet Casting.—A core box for the bonnet pattern is illustrated by the two views shown in Fig. 3 (*c*). This pattern can all be carved from one block of wood, with end boards as shown. The proper draft must

be allowed on the inside of the end boards or the core box can be made from several pieces, the divisions being along the dotted lines *a b*, *c d*, and *e f*. This latter construction would permit the turning or working out of each portion of the box separately, which will somewhat simplify the construction; but, in most cases, the large number of joints would add complications that would more than overbalance the gain. When the box is made of separate pieces, the various pieces are secured in place by gluing a board on the back of the box.

6. Pattern and Core Box for Hand Wheel.—The pattern for the hand wheel is shown in the two views given in Fig. 3 (*d*), the lower one being a section on the line *a b*. The pattern being only 6 inches in diameter may be turned from one solid piece of wood, but, when forming the arms, care should be taken to cut them so that the grain of the wood runs at an angle of 45° to the arms, which will make them of uniform strength. Another way is to turn the rim from a single piece and then let the arms into it. Square core prints are formed on the pattern, as shown in the illustration. The core prints are turned to a diameter equal to the diameter across the corners of the squares, and are subsequently cut to a square form.

The square core box for the hand-wheel core is illustrated in Fig. 3 (*e*); it is made into halves and doweled together, being parted at the two corners, so that when the core is rammed up, the box can easily be taken apart without breaking the corners of the core.

7. Patterns for Valve Details.—The pattern for the valve is shown in Fig. 2 (*e*), (*f*), and (*g*). The upper, or nut, part of the valve pattern *a* is not made fast to the valve *b*, but is located by a $\frac{1}{2}$-inch pin *c*, which is turned upon it as shown in Fig. 2 (*e*). The guide *d* is made in the same manner, but is secured permanently to the valve pattern, as shown in Fig. 2 (*f*). The pieces *e* and *f* are glued and screwed to the piece *a* after the latter has been turned.

The pattern for the valve seat is shown by the two views given in Fig. 2 (*h*). In the lower view, a portion of the pattern has been broken away so as to show the hub, or guide, *a* for the spindle on the lower portion of the valve. This hub is supported by the web *b*, as shown. The grain in this pattern should run in the direction of the axis of the seat, as indicated by the lower view. The outer ring of this pattern may be turned from a block of wood and the bridge *b* and hub *a* glued in place afterwards.

No pattern is shown for the valve spindle, as it will be similar to the one shown in Fig. 6, *Patternmaking*, Part 3. The valve seat, valve, and spindle are made of brass, and it is therefore not necessary to allow as much stock for finish on the pattern as in the case of iron castings, owing to the fact that brass castings are usually smoother.

SPECIAL THREE-WAY STOP-COCK.

8. Construction.—The three-way stop-cock described in Art. **19,** *Patternmaking*, Part 3, is of such construction that all the angles are right angles. The one illustrated in Fig. 4 is of a special design having the three passages 120° apart. The general construction of the valve will be understood by reference to Fig. 4 (*a*), (*b*), and (*c*). Fig. 4 (*a*) is an elevation of a complete cock; (*b*) is a section on the line *lm*; while (*c*) is a section on the line *jk*. In Fig. 4 (*c*) the cock is not shown as it would appear if projected from (*b*); the plug has been given a portion of a revolution so as to bring one of the openings to the front. Owing to the shape of this design of cock, it cannot be molded and cast like the one shown in Art. **19,** *Patternmaking*, Part 3.

9. Appliances for Dry-Sand Mold for Body.—For a straight-way cock there is no better way of obtaining a casting than by making a pattern; but, for a three-way body or shell of the design shown, a core box may be substituted for the pattern and made to answer the molder's requirements better than the pattern. The disadvantages

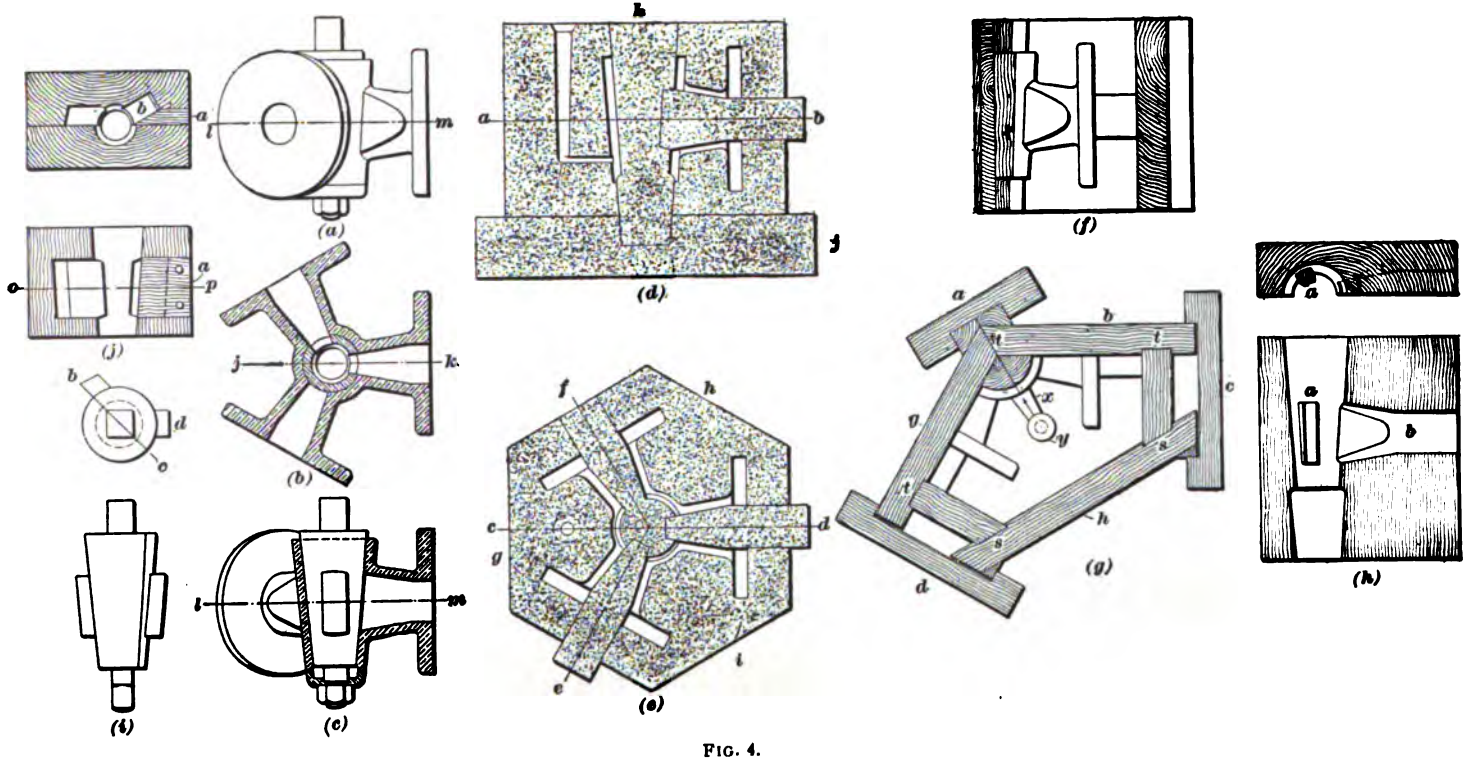

FIG. 4.

of a pattern for the shell arise from the fact that it is practically impossible to part the pattern in such a direction that it can be molded in any but a complicated flask.

10. Fig. 4 (*d*) is a vertical section of a mold for such a valve body, and Fig. 4 (*e*) is a horizontal section of the same mold. The outer part of these molds consists of three cores *g*, *h*, and *i*. These cores are joined on the radial lines passing through the points *d*, *e*, and *f*. The center and passage core on the line passing through the point *f* are made in one piece. The passage cores on the lines passing through *d* and *e* are made separate from and set into the center core. The three cores *g*, *h*, and *i* rest upon the slab core *j*, shown in Fig. 4 (*d*), but omitted in the plan in Fig. 4 (*e*). When locating the cores, the center core *k* is first set into the slab core *j*, as shown in Fig. 4 (*d*), then the cores *g* and *h* are set. These, being joined at *f*, will support the passage core on that center line. Before core *i* is set, the cores on the lines *e* and *d* are located. The ends of these cores are made to project so that the molder may either block up the ends or have a helper hold them while setting the core *i*. When all the cores have been properly set, a flask is dropped over them and sand rammed about them to keep them in place.

The core box for making the cores *g*, *h*, and *i* is shown in Fig. 4 (*f*) and (*g*). In Fig. 4 (*f*), the portions *g* and *h* of the core box have been removed, only the portion *b* being shown in place. The joints at *t*, *t* are left loose while the joints at *s*, *s* are secured by glue and screws. The parts of the box *b*, *g*, and *h* are secured together by clamps *a*, *c*, and *d*, so that, after the core is completed, the clamps may be removed and the different parts of the box drawn away from about the core, thus leaving it standing upon the core plate. The gate shown is used for only one core; *x* is separate from *y* and is drawn out in the direction of the arrow, when all the parts of the box have been taken away from the core.

11. The core box for making the center *k* and the passage core on the line *f*, Fig. 4 (*d*) and (*e*), is shown in the

two views given at Fig. 4 (*h*). The print *a* must either be given sufficient draft to allow the core to be drawn from over it, or it must be so arranged that it can be drawn out of the core through the back of the core box. Another half box to match the one shown will be necessary in order to make a complete core, or a wide box may be made having provision for two projecting arms *b*, either one of which can be stopped off at will. When this is done, it will also be necessary to construct the core print *a* so that it can be changed from one side to the other. On the whole, it is usually best to construct the two half boxes.

The core box for the passage cores on the lines *d* and *e* is not shown, as it is very simple in construction and similar to many that have already been described. Its general form is very similar to the portion *b* of the core box shown in Fig. 4 (*h*), only it will be necessary to make the box longer so as to allow the cores to project as shown in Fig. 4 (*e*).

12. Pattern for Plug.—The plug for the three-way cock has only two openings placed at an angle that coincides with the two passages of the shell, which are 120° apart. The thickness of the metal in the plug is the same as that in the shell. To make this casting, a pattern is used, though it can be made all together with cores like the shell, but a pattern in this case is probably the better method. The pattern is shown in the two views given in Fig. 4 (*i*). The pattern is parted on the line *b c* shown in the upper view. It will be seen that the core print *d* would not draw if fastened to the pattern. It should therefore be located with loose pins or wires that can be withdrawn during the process of molding, leaving the piece loose in the sand. After the pattern is withdrawn, this piece can be withdrawn also. In some cases, a section of one-half of the pattern may be arranged to be drawn separately and at an angle so that the print can be attached to it.

13. Core Box for the Plug.—The core box is made as shown in the two views, Fig. 4 (*j*), the piece *a* being put on with two pins and held in place by means of a screw or

clamp while making the core. After the core is complete, the piece *a* is removed so as to allow the finished core to be turned out. If the upper half of the core shown in the upper view Fig. 4 (*j*) were being dried by itself, the core maker would place a little green sand between the core plate and the projecting portion *b* so as to support it during drying. In the illustration, the lower view shows one-half of the core box, while the upper half shows the entire core box, both halves having been made. The core can be made in halves or in one piece, depending on the manner in which it is to be dried.

PATTERN FOR SMALL BELL.

14. General Consideration.—Molds for large bells are swept up in loam, but for small bells of such dimensions as that shown in Fig. 5, patterns are usually made. This also applies to any similar shape, such as ladles, kettles, pots, etc. In some cases, the patterns are made for comparatively large castings, especially when the metal of the casting is comparatively thick, as, for instance, slag pots for copper and lead smelters are usually cast from patterns, the castings weighing from 400 to 600 pounds, some of them being as much as 30 inches in diameter. The bell shown in Fig. 5 would be cast from bronze or bell metal and the nut *a* from brass or iron. The washer *b* might be cast from brass or made from sheet metal.

15. Making Pattern for Bell.—The right-hand side of the bell, Fig. 5, is shown in section so as to illustrate the thickness of the metal and the method of laying out the pattern. From the point *g* on the upper corner of the bell, to *h* at the edge, a straight line is drawn and divided into equal spaces. From each of these points, perpendicular lines are drawn and on each of these perpendicular lines a circle is laid off that represents the thickness of the bell at the point where the line intersects it. The distance on these

perpendicular lines from the straight line to the center of the circle is carefully determined. This information is generally furnished on the drawing for the bell. The patternmaker lays out these lines, circles, and the outline of the bell to full size, and thus determines the thickness of the courses or segments as shown on the left-hand side. As shown, the first four courses are $\frac{3}{4}$ inch thick and all the

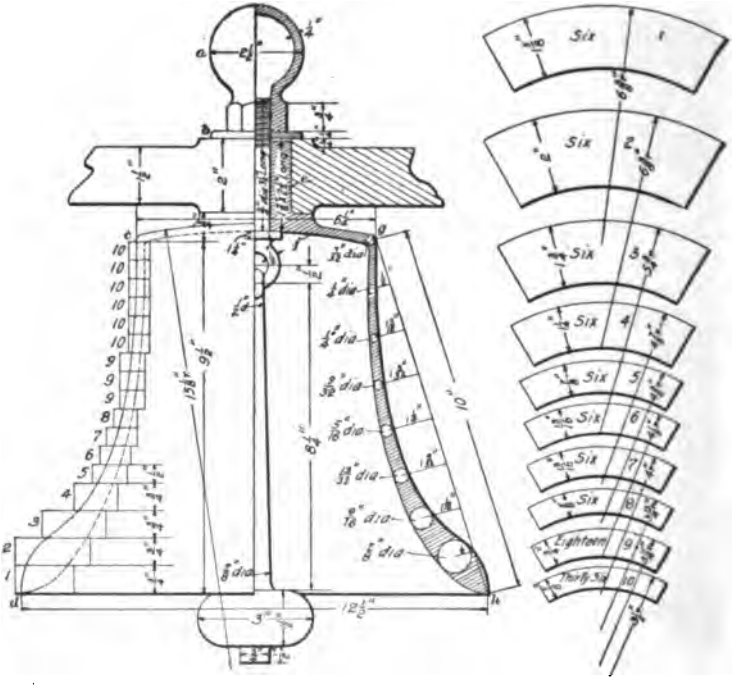

FIG. 5.

others $\frac{1}{2}$ inch. The sizes of segments and the number required are given at the right of the illustration. The proper allowance has been made for turning after the segments are in place. The segments marked *10* are for six courses and those marked *9* for three courses, each course being made up of six segments. In each of the other courses, the segments are different.

After the segments are sawed out, they should be stacked up crosswise and allowed to dry thoroughly before being built up. When dry the lower segments, marked *1*, are secured to a face plate, either by gluing on with paper between the segments and the face plate or by means of screws.

16. As the diameter of the top of the bell is comparatively small, a well-seasoned solid piece may be glued on the top of the segments and the top turned from this. The spindle *e* should be glued on after the pattern is turned, in a manner similar to a core print, a pin on the spindle fitting into a hole turned in the top of the pattern.

Before gluing on the solid piece to form the top of the bell *f*, it is advisable to turn out the part of the pattern on the inside for about 3 or 4 inches and to turn out the solid piece concave. This turning will reduce the work that must be done after the bell is chucked and will make the finishing much easier.

17. After all the segments are in place and the top *f* has been glued on, the outside of the bell is turned to the proper form, the pattern taken off the face plate at *d h* and is chucked on the outside at the small end. The chucking is done by fastening four pieces of wood about 2½ inches thick on the face plate with glue or screws, and turning them on the inside so that the pattern fits tightly between them, or a thick piece of plank may be fastened to the face plate and turned out so as to fit the outside of the pattern. Great care must be taken in this operation, as the friction between the pattern and the chuck holds the pattern while turning, otherwise the pattern may fly out of the lathe. A 1¾-inch No. 16 screw may be used at the center through the face plate to secure the pattern in the chuck, as the bell is slightly tapered for 2½ inches, making it liable to work out from the face plate if the screw is not used.

In the case of many small patterns that are turned in this manner, a good patternmaker will depend entirely on the friction of a good fit for turning the pattern.

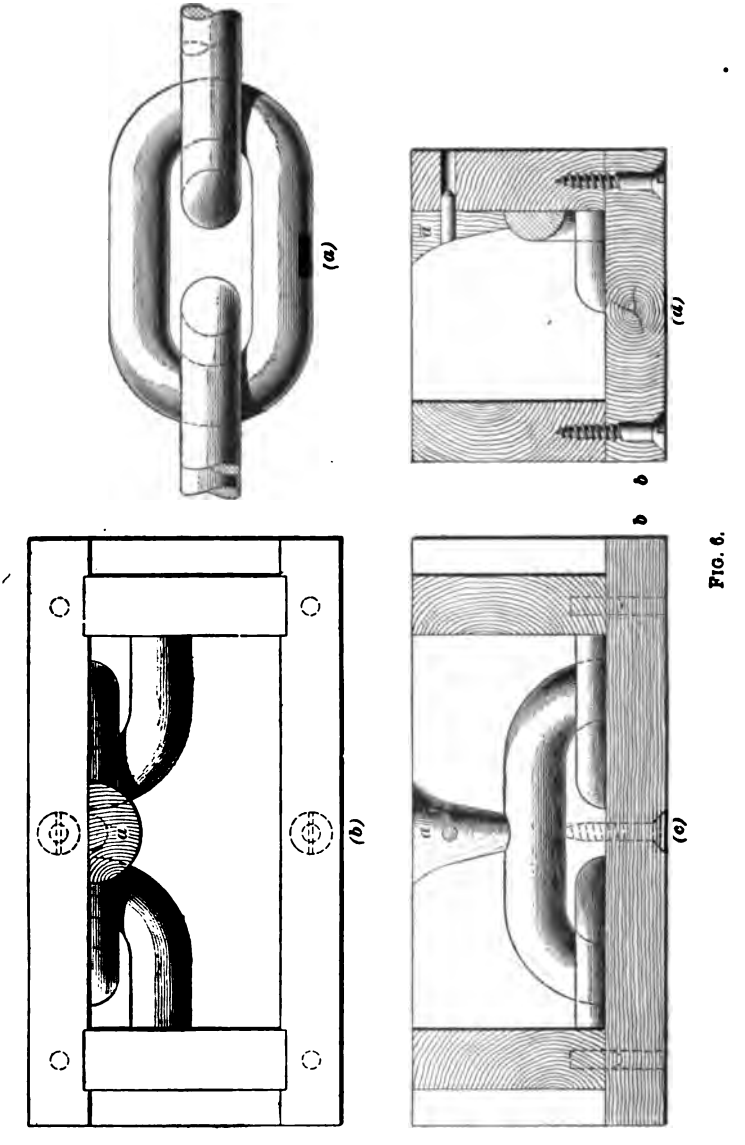

FIG. 6.

18. A patternmaker sometimes dampens the outside of the pattern slightly to produce a tight fit by causing the pattern to swell into the chuck. This is one of the tricks of the trade, but is not to be recommended, as the wood may expand with such force as to distort the pattern; also, if the turning takes some time, the moisture may dry out and loosen the pattern in the chuck. The inside of the bell is turned to a templet while the pattern is held in the chuck, after which the spindle is put in place. Some prefer to begin with the top of the bell and build the segments on it. In this case the top is secured to the face plate, the outside roughed off so as to run true, the inside turned out and finished, and then the outside finished. This method saves chucking and allows the outside to be finished last.

The patterns for the nut *a* and the washer *b* are so simple that they will not be illustrated. The pattern for the nut would be parted through the center line, and must be made with a long core print for supporting the core, similar to the pattern shown in Fig. 9, *Patternmaking*, Part 1.

PATTERNS AND CORE BOX FOR CASTING CHAIN.

19. A chain is sometimes cast of strong bronze for marine or other purposes, especially where iron would corrode excessively, but such chains are so costly that they will never be generally used. One link and the connections to the two adjacent links of a chain are shown in Fig. 6 (*a*). Each link passes through two others, and hence the mold for casting the entire chain at once would be very complicated, as would also the system of gating. To overcome this, one-half of the links may be cast separate and then provision made for casting the other links through these.

20. Patterns for Links.—In constructing the link pattern, wood is used for the first pattern, a double allowance for shrinkage being made. The pattern need not be parted, but may be cut from a solid piece of wood. The

allowances for shrinkage should be one for aluminum ($\frac{1}{4}$ inch to the foot) and one for bronze ($\frac{3}{16}$ inch to the foot). In making the link, its form is first marked out and cut to a square cross-section inside and out. Then the edges are chamfered to a 45° line tangent to the circle of stock in the link, after which it can be whittled round.

This pattern could also be made by turning a ring with the radius equal to the end of the link, cutting it in halves for the ends and then joining these half rings by two straight cylindrical pieces to form the sides of the links, but there is much less work in the first method than in the second, because the turning and fitting take more time, and then, too, the pattern made by the second method is not as strong as the one cut from a solid piece of wood.

Four or more aluminum patterns are now cast from the wooden one and made smooth, after which they are sunk one-half of their depth into the molding board and a gate fastened on the latter. This simple provision allows several links to be molded at once. At times, the links are split and attached to the opposite sides of a card pattern on account of the fact that one-half of all the links of the chain must be cast in this way and the card pattern greatly facilitates the molding. The bronze links cast from the aluminum patterns have the gates cut off and are partially finished and smoothed up before being cast into the chain proper.

21. In order to join the bronze links already cast, special dry sand molds are employed. Fig. 7 (*a*) shows two bronze links *a* and *b*, which have been placed between the cores of the dry sand mold. The link *c* is then cast in such a position as to join the separate links *a* and *b*. One of the four cores has been removed so as to show the arrangement of the links, and one of the separate cores is shown at Fig. 7 (*b*). Several links *c* are cast at one time by setting a number of cores in a long box made for the purpose, and having the corresponding number of links in the positions occupied by the links *a* and *b*, Fig. 7 (*a*).

22. The core boxes for forming the cores shown in Fig. 7 are illustrated in Fig. 6 (*b*), (*c*), and (*d*). These core boxes should be made of hard wood, or, if a great number of castings are required, from metal. When they are made from metal, it will be necessary to make patterns for them and to allow the necessary shrinkage on the patterns. The construction of the wooden box will be described. The link portions are made of aluminum and secured to the wood. It will be seen that the link parts in the box must be accurately located or they will not coincide when the cores are placed together. The ends, sides, and bottom of the boxes are so arranged that they may easily be removed when the core is rammed up and turned over on the core plate

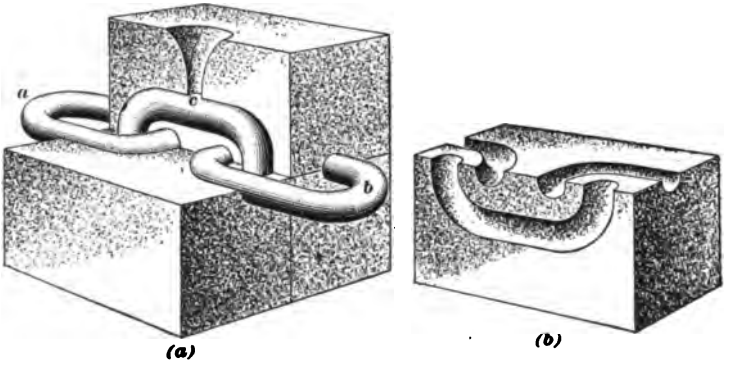

FIG. 7.

The bottom *b*, shown in Fig. 6 (*c*) and (*d*), is secured to the sides by screws or clamps, and the four dowel-pins shown in the sides are for the purpose of locating them each time a core is made. When it is desired to remove the cores from the boxes, the screws or clamps are removed and the bottom taken off carefully, after which the sides are taken away, leaving the core on the core plate.

The gate shown doweled on at *a*, Fig. 6 (*b*), (*c*), and (*d*), is so arranged because it is required in only one-half of the cores, those intended for the lower portion of the molds shown in Fig. 7 (*a*) requiring no gating.

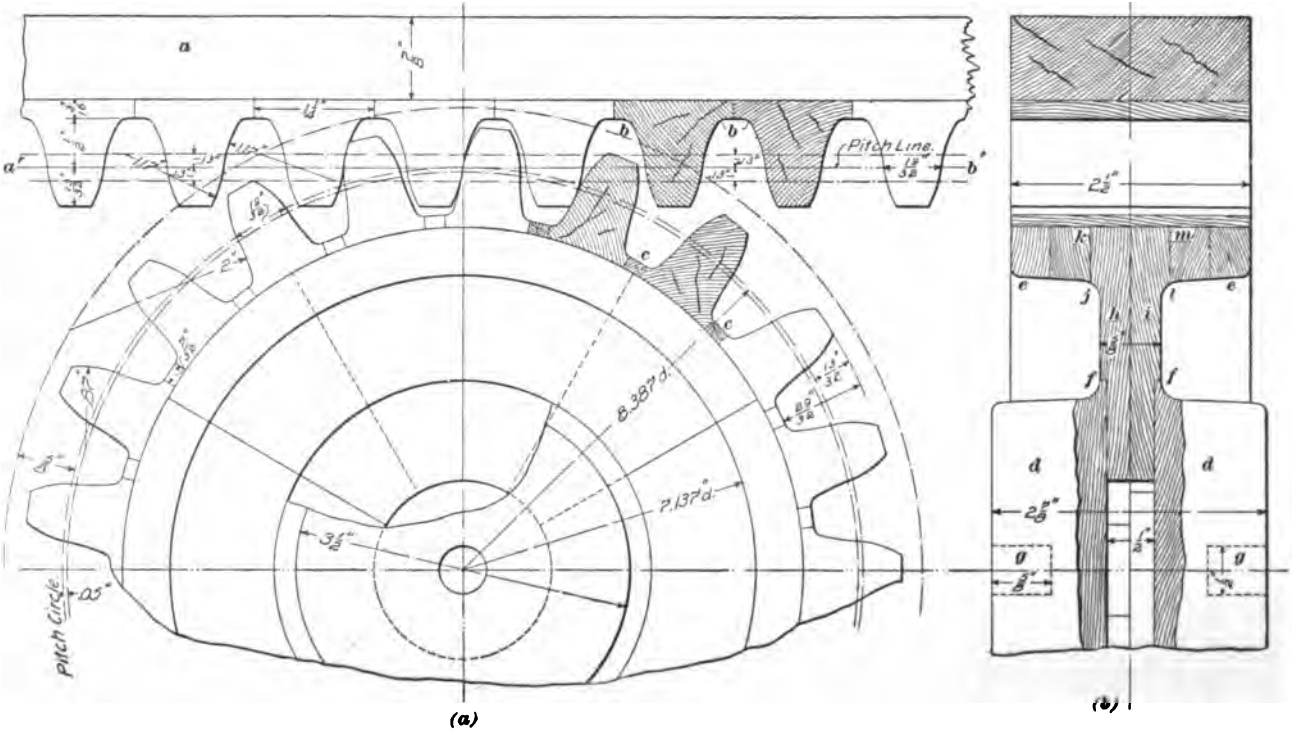

FIG. 8.

PATTERNS FOR SPUR GEAR AND RACK.

23. Preparation of the Stock for Patterns.—The patterns shown in the views in Fig. 8 are those of a spur gear and rack and the method of making them will be described. The circular pitch is $1\frac{1}{4}$ inches, the face $2\frac{1}{2}$ inches, the rack is 25 inches long, and the pinion has 21 teeth, which will give it a pitch diameter of 8.387 inches.

The stock should be carefully selected, first-quality clear pine. The segments of the rim of the gear should be sawed out and the lumber dressed $\frac{1}{16}$ inch thicker than the finished thickness of the segments, after which the pieces should be stacked crosswise and allowed to dry thoroughly. After this, the stock for the hubs and rack is prepared from the same quality of lumber.

24. Rack Pattern. — The plate, or back, *a* for the rack is about 25 inches long, $\frac{7}{8}$ inch thick, and $2\frac{1}{2}$ inches wide, and should be carefully planed straight, parallel, and square with the edges. To make the teeth of the rack, blocks are dressed $1\frac{1}{4}$ in. $\times$ $1\frac{3}{32}$ in. $\times$ $2\frac{1}{2}$ in. long. The best way to cut these out is to plane up three sticks each 16 inches long, from which the required number of blocks may be cut. To allow for dressing off the ends of the blocks after they are fastened to the plate of the rack, they should be cut about $\frac{1}{8}$ inch longer than the width of the rack. Each of these blocks should be screwed on from the back of the rack with $1\frac{1}{2}$-inch No. 10 screws, no glue being used at first. The teeth are then marked out on the blocks, after which they are removed and cut to the desired shape. Each tooth should be formed, glued, and screwed in place before the next one is removed, making it possible to replace the teeth accurately.

25. Fastening the Teeth on the Gear and Rack Bodies.—The advantage of fastening the teeth of gears in the manner shown, over the old way of dovetailing, is that the fillets *b* at the bases or roots of the teeth can be formed in the blocks from which the teeth are cut, thus making the whole structure stronger. Fillets or round corners at the

bases of the teeth are very desirable, insomuch as they add strength, rendering the pattern better for molding, and also removing, in a large degree, the effect of cracks at the base of the teeth, due to irregular shrinkage that takes place where sharp angles are left in the casting.

In the rack pattern, it will be seen that there are no pieces fitted between the teeth as shown at *c* on the pinion. The object of this is to show the different methods that may be adopted for making the gears with fine or coarse pitches. The method employed in the case of the rack is that used for fine pitches, while that employed in the gear is the method suitable for coarse pitches. On account of the fact that the spaces between the large teeth become greater, it becomes necessary to insert a strip between them, as shown, otherwise it would not be easy to work out the teeth from the blocks, which are carried to the center of the space like those in the rack; besides this, the thin parts produced thereby would probably curl up and cause trouble. The strips put between the teeth not only make it convenient to shape them, but act as guides for locating them again after they have been removed for shaping.

26. Building Up the Gear Pattern. — When the rack is completed, and the blocks for the teeth and strips that go between them are prepared for the pinion, the hub should be turned as represented at *d*, Fig. 8 (*b*). After this, the six courses or segments may be built up. A wooden face plate, upon which to turn the wheel, is turned about $\frac{1}{4}$ inch larger in diameter than the inside of the rim of the pinion, and, as both sides of the pattern cannot be turned without chucking, either of the faces *j k* or *l m* may be placed in contact with the face plate. The segments *h* or *i* of the web should be the first to be jointed and laid in place upon the face plate. Before doing so, six pieces of paper about $1\frac{1}{2}$ inches wide should be glued on the face plate where the joints of the segments will come. Then the ends of the segments should be glued by putting a little glue on the paper. The first course will then be held to the face

plate by these six pieces of paper, and, when dried, may be faced off true and to the proper thickness in the lathe, ready for the next course.

When one side is built, the inside should be turned and finished to dimensions, as shown at *e*, Fig. 8 (*b*), and the web recessed to fit the edge of the fillet on one of the hubs already turned, as shown at *f*. The outside of the gear should also be roughed off. The pattern is now removed from the face plate, and the edges of the face plate turned to fit the inside *e* of the part just removed. The pattern can be fastened to the face plate with three screws and the other half built up. After this side of the pattern is completed, the inside is turned out and the outside turned to the correct diameter.

27. The blocks that are to form the teeth and the strips that go between them should now be fitted and fastened on, the blocks and the strips being placed alternately around the circumference. The blocks on the rim are secured by screwing them on from the inside with 1-inch No. 8 screws. The strips are fastened in place with glue and fine $\frac{1}{2}$-inch wire brads. All this should be done before taking the pattern from the face plate, because the ends of the blocks must be turned off flush with the rim, and the circles on which the tooth-curve centers are located, marked in the lathe. Before facing off the ends of the blocks, pieces that will just fill the space between the blocks must be fitted and glued between the ends to prevent them from splitting while turning. The grain of the wood in the pieces should run in the same direction as that in the tooth. These pieces will also serve to support the points of the compasses when laying out the curves for the faces of the teeth. When the curves for the teeth are marked out, the filling pieces placed between the teeth should be taken out and the tooth blocks removed and numbered consecutively on the inside and their places on the rim should be marked with corresponding numbers. The teeth are then worked off, after which they should be glued and screwed back in their respective places.

28. The hubs may also be glued in place after the teeth are completed, but the core prints should be left loose,

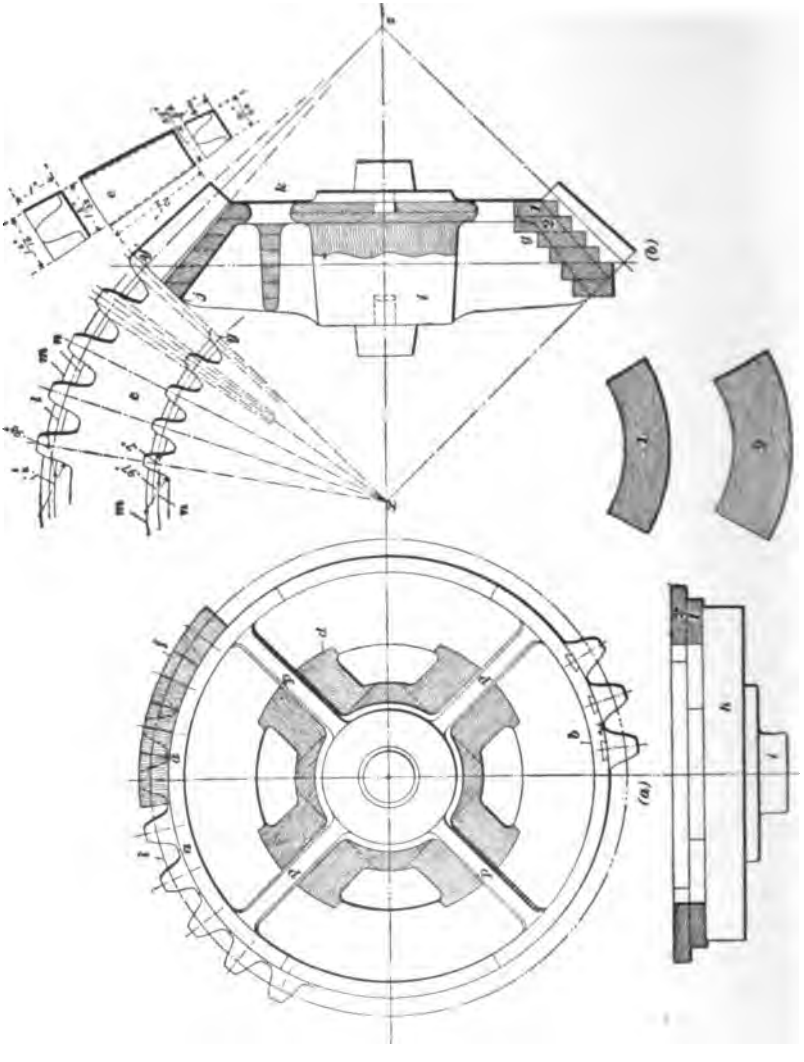

FIG. 9.

as the size of the bore is frequently changed, making other core prints necessary. Sometimes the hubs of gears are

also left loose for this same reason. This enables one to introduce larger or smaller hubs that will admit of being bored to larger or smaller diameters. In Fig. 8 (*b*), the hubs are shown in place and the dotted lines at *g* indicate the position of the holes for receiving the pins for the core prints, but the core prints are not shown in place.

MITER- AND BEVEL-GEAR PATTERNS.

29. General Consideration.—To cast a pair of miter gears (gears making an angle of 45°) that will mesh and run together, only one pattern is required, while, in order to cast a pair of other bevel gears, two patterns are necessary, because the angle in each is not the same on the face and they each contain a different number of teeth.

When looking for a certain gear pattern among others, an experienced patternmaker can generally distinguish the difference between a miter and any other bevel gear without trying the angle, but where there is only a small difference, it is not easy to distinguish between them without testing their angles or referring to the records. For this reason, it is well to stamp the word "miter" or "45°" on all miter-gear patterns. The method of constructing a pattern for either miter or bevel gears is the same, and only one example need be considered.

30. Pattern for Bevel Gear.—The method of making the gear pattern shown in Fig. 9 (*a*) and (*b*) is not a general one, differing from common practice in the way in which the teeth are fastened. The teeth are usually dovetailed into the rim, as shown at *b*, Fig. 9 (*a*), the dovetail being made with a slight taper so that the teeth can readily be driven out and replaced. Another method sometimes employed consists of gluing the blocks for the teeth on the rim without dovetailing them and then shaping them while in place. The rim of the wheel in both instances is turned to the correct diameter at the root of the teeth. In the method shown at *a*, Fig. 9 (*a*), it will be seen that the rim

is turned under the size and then the blocks for the teeth are formed so as to make up the difference.

The first of these three methods has many points to commend it, as it allows the blocks to be removed for dressing the teeth separately. It does not, however, permit the fillet to be worked out at the bottom of the tooth. The second method is not good, because if the fillet is made at the root of the tooth, the feather edge thus formed is liable to curl up. Another bad feature of this second method is that all the teeth must be dressed off in place, which is not so easy to do as when the blocks are removed or when every second one is removed. The method shown at *a* has the advantage of having a fillet at the root of the tooth without the feather edge, and of permitting every other block to be removed for the purpose of shaping the teeth. It will also be seen that all the joints of the segments forming the ring are covered between the teeth, which is a desirable feature.

31. To make a pattern of this type, a full-sized section of the rim must first be drawn as shown at *g*, Fig. 9 (*b*), in order to lay out the width, thickness, and diameter of the courses of segments. In the pattern illustrated, six segments are used.

The profiles of the outer and inner ends of the teeth that are shown at *c* are drawn in the same way as the teeth for two spur gears whose radii are xy and xy', with pitches corresponding to the inner and outer ends of the tooth. It is seldom that the two circles y and y' can be spaced without a remainder, but this fact is of no account as they are only auxiliary circles that are used for convenience in laying out. In building up the rim, a wooden face plate *h*, Fig. 9 (*c*), is employed. This is screwed to an iron face plate *i* and the segments are glued to the wooden face plate, the course marked *1* being glued on first with a piece of paper under each joint.

The course of segments *2* is next glued on the course *1* and faced off, and the succeeding ones added until all are in

place. The rim is then turned inside and roughed off on the outside. Before removing the pattern from the face plate, the four arms should be let in and glued to the rim, as shown at *d*, Fig. 9 (*a*), the arms having previously been half checked together and formed to the required shape. The hub is turned on a screw chuck and left a little larger than the required size. It is then glued to the arms, and, when the glue is thoroughly dry, the arms are faced off and the hub finished so that it will run exactly concentric with the rim, thus enabling the patternmaker to chuck the pattern by means of the hub. The wooden face plate *h*, Fig. 9 (*c*), used in turning up the outside and inside of the pattern, is made smaller than the diameter of the gear at the small end, so as to allow the outside of the gear to be roughed off during the first operation.

32. After the pattern is removed from the face plate, a larger wooden face plate is provided, having a piece at the center so as to allow a greater thickness of stock to receive the hub. The center part of the face plate is turned to receive the hub *i*, Fig. 9 (*b*), and the corner of the pattern *j* is allowed to rest against the face plate so as to act as a support and prevent the pattern from trembling while turning the outside of the teeth. After the pattern is chucked, the face *k* and the outside are turned to the required dimensions, ready to receive the teeth. The hub and the core print may also be added and turned.

33. Fastening and Forming the Teeth.—In getting out the blocks for the teeth, they should be made about $\frac{1}{16}$ inch longer than those shown at *e* in order that the ends may be turned off. The rim having been turned, it is spaced off on the face for the teeth, the lines being drawn toward *z* by the use of a center square. The blocks for the teeth are fitted on the rim, as shown at *f*, Fig. 9 (*a*). All the blocks are glued together above the root of the finished tooth, on the sides, near the outer ends, but only every alternate one is glued to the rim. They are thus secured for turning. Particular care must be taken when gluing,

not to allow any glue to get on the sides of the blocks near the rim, as at *a*, Fig. 9 (*a*), or below the bottom of the finished tooth, and only freshly made, thin glue should be used.

When the glue is thoroughly dry, the ends and faces of the blocks may be turned. To make a good surface for marking the teeth, a light coat of yellow varnish should be given to the blocks and when dry they should be sandpapered. The pitch circle *l* and the circles *m* and *n* for the centers of the arcs forming the tooth curves are drawn on both ends of the gear, after which the profiles of the teeth are laid off on the inside and outside.

After this laying out is done, the joints of the blocks are sawed down all around to the bottom of the glue, relieving them and allowing every alternate one to be removed, thus rendering the paring of the teeth much easier than if all were glued onto the rim. When removing the blocks for paring, they should be numbered so that they can be properly replaced. After all the teeth are completed, those that have been removed are replaced and glued to the rim. The fillets at the bottoms of the teeth are formed from the blocks from which the teeth are formed. In the case of gears of large pitch, it may be necessary to introduce strips of wood between the teeth, as in the case of the gear illustrated in Fig. 8. The ribs *p* are fitted in place after the turning is complete, because, if they were introduced before the chucking, they would interfere with the chuck.

WORM AND WORM-GEAR PATTERNS.

WORM PATTERN.

34. Preparation of the Stock.—If it is required to make a pattern for a worm 4 inches in diameter with a single right-hand thread having $1\frac{3}{4}$ inches pitch, the following course may be pursued. First, turn the pattern, which should be in halves, to the required diameter and length, as shown in Fig. 10 (*a*). The core prints *a* and *b* may be

turned on the pattern, as shown, or they may be turned afterwards and attached to the pattern. When turning such a pattern as this, it is best to have metallic plates attached to the ends and to use conical centers. This will enable the work to be returned to the lathe after the threads are cut, so that the threads may be sandpapered while the lathe is revolving at a slow speed. A much better job of sandpapering than could otherwise be done is thus insured.

35. Laying Out the Thread.—After turning the pattern, a piece of paper should be wrapped around it and

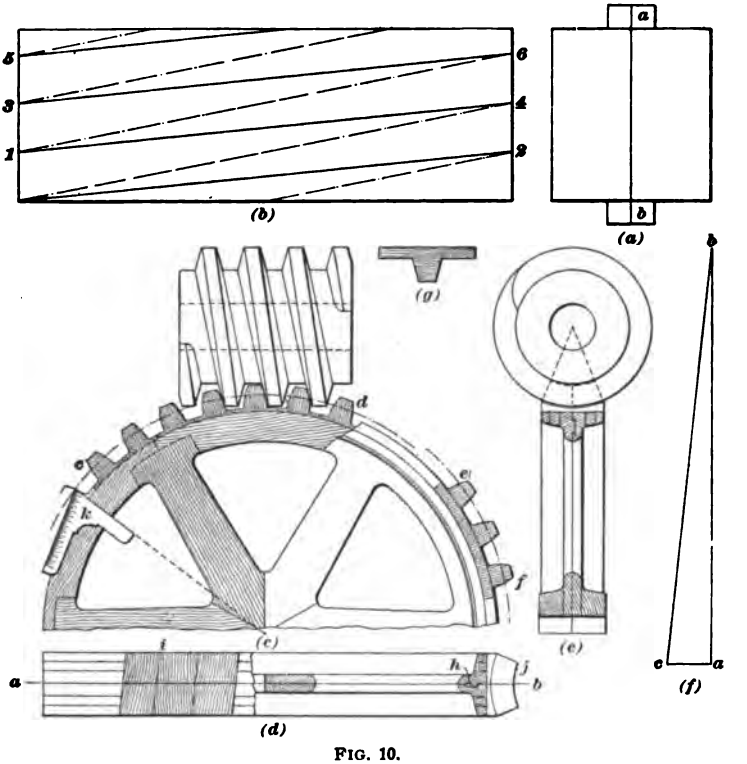

FIG. 10.

cut to the exact length of the circumference and also the length of the pattern. The paper should then be laid off as shown in Fig. 10 (*b*). The points *1*, *3*, *5* and *2*, *4*, *6* are laid

off on the edges of the paper 1¼ inches apart and the full lines drawn connecting them, as shown. These lines represent the center line of the thread. After the lines are drawn, the paper is wrapped around the pattern again, when it will be found that point *1* will meet point *2*, point *3* will meet point *4*, and point *5* will meet point *6*, thus making one continuous line when wrapped on the pattern. The paper is finally glued on to the pattern, but, before this is done, other lines should be drawn parallel to these, representing the thickness of the thread or the lines upon which it is desired to saw down for the sides of the thread.

36. In laying out the lines, care must be taken not to run the thread in the wrong direction, making a right-hand instead of a left-hand or a left-hand instead of a right-hand thread. This mistake is very easily made. If the thread is to be a right-hand, the lines should run up toward the right hand, as seen in Fig. 10 (*b*), and if it is to be a left-hand thread, they should run up toward the left.

37. When a double thread is required, instead of starting to draw the lines from point *2* to the corner, point *1* to point *4*, point *3* to point *6*, etc., they should be drawn as indicated by the broken lines, so that each line advances two divisions instead of one. By following out this system, any number of threads can be drawn. If the lines advance three points, a triple thread would be formed; if they advance four points, a quadruple thread, and so on, until the number of threads and the angle are so great that it is called a spiral gear in place of a worm.

38. If the entire surface of the paper were covered with glue, the moisture of the glue would stretch it so that the ends, instead of meeting, would overlap. This can be avoided by simply placing a little glue along the ends and a spot here and there on the inside of the paper, and not covering the entire surface with glue. After this is done, the paper should be laid down and the pattern rolled over it, when the paper will adhere to the pattern and take its proper position.

39. Forming the Thread.—The cutting of the thread may be done with a back saw, but, before beginning the work, two pieces of hard wood about $\frac{1}{4}$ inch thick should be fastened to the sides of the saw to act as guides and to prevent the saw from cutting beyond the desired depth. With the saw thus prepared, two spiral lines may be sawed about the worm and the space between removed with a chisel, after which the form of the thread can be finished out to a templet, as shown in Fig. 10 (*g*). The form and angle of this templet will depend on the kind of thread to be cut.

Some patternmakers have two small holes drilled through their back saw to enable them to fasten wooden guides upon it, while others allow the guides to project beyond the ends of the saw to secure them together by means of screws. After the thread has been formed to the desired shape, the pattern may again be placed in the lathe and sandpapered.

A worm, especially long worms, may be roughed out on a circular saw. The worm is turned to the desired diameter, the spiral laid out upon it, and one or two turns worked out $\frac{3}{16}$ or $\frac{1}{4}$ of an inch deep at one end, so as to form a guide. A wooden box or guide is so placed on the saw table that the saw will enter the groove parallel to the thread of the worm. A small pin one turn in advance of the saw blade engages the groove which has been worked out by hand. The operator rotates the worm against the guide by hand, and the small pin feeds it along the guide. The saw cuts a groove which is a continuation of the groove worked out by hand, and after the guide pin has passed the portion worked out by hand, it engages the portion cut by the saw, and the work becomes continuous. A groove $\frac{3}{16}$ to $\frac{1}{4}$ inch deep is sawed down on each side of the thread the entire length of the worm. The saw is then moved over and the table lowered slightly so that another cut can be taken next to the one previously made. The guide pin must be readjusted each time so that the saw will rough out the stock almost to the face of the thread. By repeating this operation, practically all the material in the groove can be sawed out in a very short time.

PATTERN FOR WORM-GEAR.

40. Requirements and Form of Tooth. — If a worm-gear is to mesh with the worm described in Arts. **34** to **39,** the wheel being 21¾ inches in diameter, 1¾ inches pitch, and having 39 involute teeth, the work may be done as here described. Involute teeth may be laid out by the Willis odontograph, as described later. Many patternmakers shape the thread of a worm the same as that of the tooth of the gear in which it is to work, but in this case the sides of the thread have the form of involute teeth and should be straight and at an angle of 75° with the axis of the worm. This is the correct form for the involute rack tooth and the worm is similar to the rack in this case.

41. Building Up the Body of the Pattern.—A section of a worm-gear pattern is shown in Fig. 10 (*d*), the pattern being parted on the line *a b*. In turning the pattern, the face plate should be the same diameter as the rim so as to allow the ends of the teeth to be turned off. Each half of the pattern should be built up separately with the parting joint of the pattern against the face plate. The outside of both halves of the pattern should be roughed off and the inside faces of the arms finished carefully, care being taken to turn the inside of both halves to the same diameter so as to make the chucking easier. When this is done, the rings are chucked by the inside of the rim so that the parting face of the pattern is on the outside. If the arms have already been placed in the pattern, this chucking may be accomplished by means of segments nailed or glued to the face plate, and so placed that they will fit between the arms. The outside of these segments is then turned so that the pattern will just fit over them. The outside of the rim should then be finished to the required size and blocks for the teeth fitted upon the periphery.

42. Fastening and Facing the Teeth.—The blocks for the teeth should be fitted and glued on with the grain of the wood running at the same angle as the teeth at the

pitch line, the width of each block being equal to the pitch. The angle of the teeth is laid out as shown in Fig. 10 (*f*), in which *a b* represents the circumference of the worm on the pitch line and *a c* the pitch, while the angle *a b c* will represent the angle of the teeth at the pitch line. The three blocks at *i*, Fig. 10 (*d*), are shown fastened on at the proper angle. These blocks are fastened on before taking the first half of the pattern from the lathe and they should be faced off true with the parting line of the pattern. The groove shown at *h*, Fig. 10 (*d*), may also be turned at this time.

After the first half of the pattern has been turned and removed, the second half is chucked and turned and the blocks for the teeth fitted on, care being taken to so place the blocks that they will come in line with those on the first half when the arms of the pattern are in their proper position. A projection should also be turned upon the pattern to fit the groove *h*, Fig. 10 (*d*), and this groove and projection will serve to locate the two halves of the pattern concentric with each other when they are brought together.

The two halves should now be put together before the second half is removed from the lathe, the second half being secured to the first half by means of screws or clamps. The blocks for the teeth should be turned off on the ends and finished to the proper form, as shown at *j*, Fig. 10 (*d*). To provide a good surface for laying out the teeth, the blocks should be varnished yellow and sandpapered.

43. Laying Out and Forming the Teeth.—In Fig. 10 (*c*) a series of teeth is shown from *c* to *d* with one-half of the gear pattern removed so that the section of the teeth on the center line and their contact with the worm may be more clearly illustrated. The projection of the portion of the teeth that extends beyond the center line is not drawn in. In the portion of the figure from *e* to *f*, three teeth are shown, illustrating an end view of them. Owing to the fact that the teeth on the outside edge of the worm-wheel have a greater pitch diameter than those in the throat, they will have a greater chord pitch, and hence if

the teeth are formed of the same cross-section clear across the face of the worm-wheel, the worm will not fit them perfectly. The longer the portion of the worm which engages the worm-wheel, the greater the error which can be produced from this cause. To remedy this, the outer ends of the teeth should be cut thinner than the theoretic thickness. In order to determine the amount to be pared off from the outer ends of the teeth, it should first be determined how many of the teeth of the worm-wheel are in contact with the worm at one time, and a pair of dividers should be set to this contact distance. This distance can then be compared with the thickness of the teeth at the outside edge, when it will be found that the dividers are set to a considerably smaller dimension than the over-all dimension of the corresponding number of teeth. One-half of the difference between the divider setting and the over-all distance of the teeth at the outside of the worm-wheel should be pared off from each side of the teeth at the outer edge, and this amount should taper to nothing at the center. In laying out the amount to be removed, measurements may be taken at two or three points along the teeth. This error is very much more noticeable in worms having a long contact.

44. In the form of teeth shown, the tooth curves may be struck in with a compass, providing the proper center has been ascertained. This is done by means of the odontograph, which is shown at *k*, Fig. 10 (*c*). The odontograph is shown more plainly at *a*, Fig. 11. The instrument consists of a 75° angle divided off into $\frac{1}{4}$-inch spaces on one side for 4 inches in length, the $\frac{1}{4}$-inch spaces being subdivided. When in use, the zero point of the instrument is placed at a point on the pitch line that corresponds with an intersection of the face of one of the teeth with the pitch line, and the plain side *c d* of the instrument is placed on a radial line, as indicated in Fig. 11. A distance corresponding to the radius of the gear is then read off on the graduated side of the instrument, the quarter-inch spaces

being read as inches. This will locate a point from which the tooth curve can be struck. In the case of the wheel under consideration, the diameter is $21\frac{3}{4}$ inches and the radius $10\frac{7}{8}$ inches. This is so near 11 inches that, for practical purposes, 11 inches could be read off on the odontograph and the point placed for the center of the tooth curve.

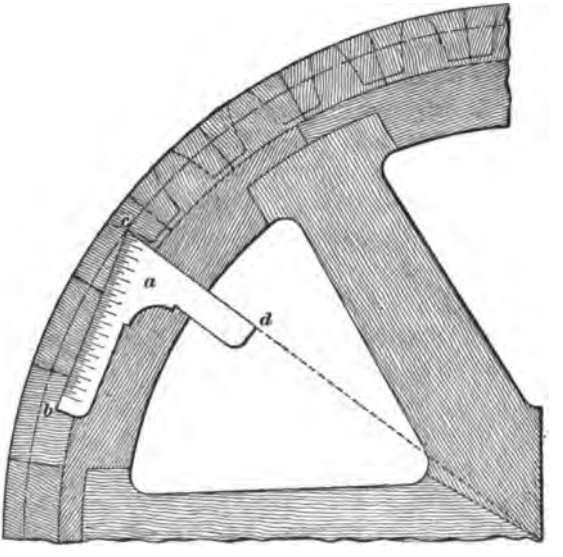

FIG. 11.

This method is continued around the entire gear. The diameter of the circles containing the centers of the circles forming the tooth curves are usually furnished by the drawing room and placed upon the drawing. When this is not done, the odontograph may be used.

45. To insure the proper angle on the face of the tooth, the center of one of the blocks on each side may be located on the pitch line and the spacing on the two sides continued from this. If the blocks have been placed at the proper angle, this will insure the teeth being at the proper angle. It is also well to take the pattern apart and lay off the tooth curves at the center on one-half of the gear. This half is

then trimmed to the proper form and placed in contact with the other half, after which the remaining portion of the teeth can be shaped.

46. Strengthening the Pattern Arms.—Since the arms of the pattern are made in halves, they are thin, and therefore weak. In order to give them the greatest possible amount of strength, the joints at the center should be tongued and the hub on each side glued and screwed to the arms, which will, in most cases, give the requisite amount of strength. Only one dowel-pin will be necessary to insure the halves of the pattern going into their correct positions, as the annular groove and tongue shown at *h*, Fig. 10 (*d*), will center them, and all that is necessary is to bring the teeth into the correct relationship on both halves.

FLYWHEELS WITH HOLLOW ARMS.

47. Advantages of the Different Designs of Flywheels.—Many persons contend that flywheels whose rims are made in 8 or 10 sections would be just as strong if cast in halves. When the rim is made in a number of sections, the arms and hub are made separate and the parts bolted together; while, when the wheel is cast in halves, the arms and rim are usually cast together. It is certainly cheaper to cast wheels in halves than in a large number of segments. The matter of first cost, however, should always be made secondary to that of durability and strength, on account of the fact that a bursting flywheel is liable to cause great damage.

48. The method of making the wheel in sections possesses certain advantages, among which may be named the fact that it is more easily handled in the shop and is not subject to as great strain from shrinkage as one made in halves. On the other hand, when the wheel is made in sections, there is danger of the loosening of the bolts and joints, and a wheel built in sections is generally more difficult to balance than one cast in halves. Flywheels with solid arms

are often cast in halves, especially when of comparatively small diameter. The flywheel described in the following articles and illustrated in Fig. 12 is 20 feet in diameter with

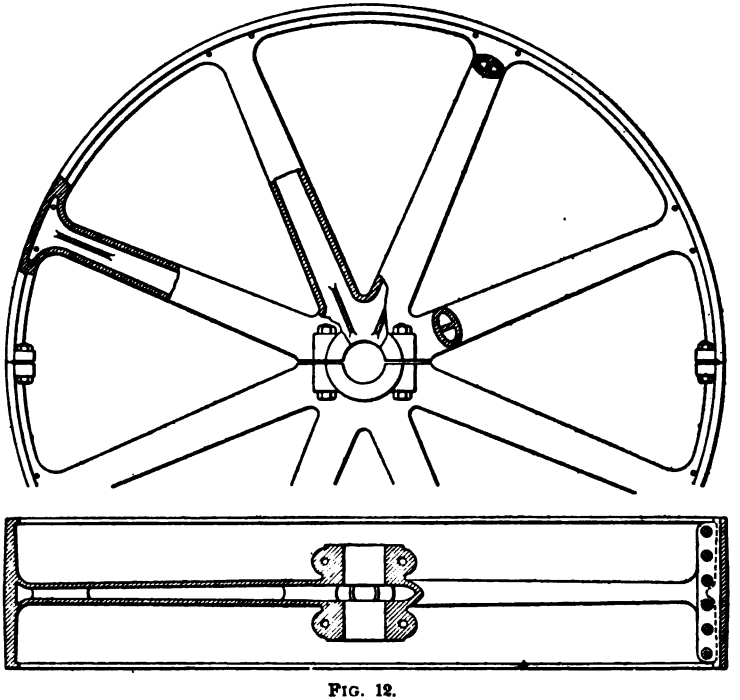

FIG. 12.

a 50-inch face, and weighs about 22 tons. It was successfully cast in the kind of mold described and has been running for several years. Ordinarily, such a large wheel would have been cast in sections.

49. Strength of Arms.—The necessity of making a flywheel strong enough to withstand the shrinkage strains of cast iron while cooling is sometimes overlooked. The cross-section at the small part of the arm may be made large enough to withstand all working strains, but not strong enough to withstand the strains due to cooling. For this reason, most flywheels that give out crack while cooling in the foundry. This cracking is usually due to an

insufficient amount of metal in the arms, compared with the other parts, thus causing the arms to cool too quickly. The molder often prevents this by uncovering the heavy parts of the casting first, especially the hub, thus allowing the whole casting to cool simultaneously, or nearly so. The shrinkage strains, however, may be so great, owing to ill proportioning, that, with all the precautions a molder can take, the wheel will break, and hence the draftsman should always consider the shrinkage strains when designing the flywheel arms, and the patternmaker should have sufficient knowledge of molding so that he will be able to judge as to the results that will occur when making any given casting and will also be able to help the draftsman in correcting any faulty designs.

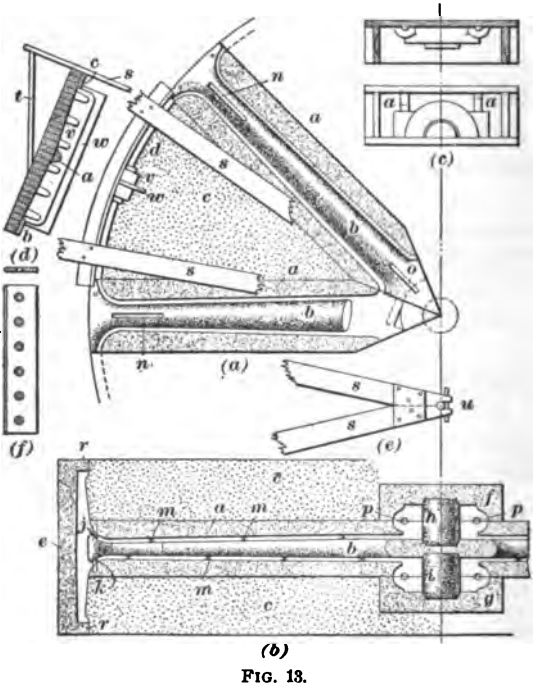

FIG. 13.

50. General Consideration of Flywheel Mold. The flywheel shown in Fig. 12 may be molded as shown in

Fig. 13, the greater part of the mold being composed of dry-sand cores. The portion of the mold for the arms is formed by the outside cores shown at *a*, Fig. 13 (*a*) and (*b*). The cores to form the inside of the arms are shown at *b*. The space *c* between the cores *a* and the rim of the wheel *d* is filled with green sand, which is rammed against a part pattern, as shown. The outside of the mold is composed of curved cores *e*, Fig. 13 (*b*); the portion of the mold for the hub is formed by the cores *f* and *g*, while the opening through the hub is made by the cores *h* and *i*.

51. Appliances for Making Cores for the Outside of the Arms.—A core box for the outside of the arms is shown in Fig. 14 (*a*) and is fitted with interchangeable pieces *a* in the end of the box. These interchangeable pieces are for forming the hub, or rather for forming the space for the hub cores. In Fig. 14 (*b*) is shown a plan of the hub cores, and three sections must be made to correspond with those numbered *1*, *2*, and *3*. These three sections are used at *a*, Fig. 14 (*a*), in forming the arm cores. By reference to Fig. 13 (*b*), it will be seen that the cores *b* are supported at their outer end upon the cores *j* and *k*, and also by chaplets *m*. In order to provide for the cores *j* and *k*, the core box shown in Fig. 14 (*a*) must be provided with core prints *b*. These are also shown in the partial sections of the core box, Fig. 14 (*c*) and (*d*).

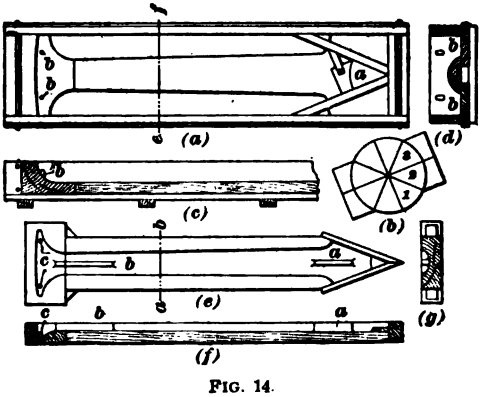

FIG. 14.

52. Core Box for Inside Arm Cores.—A core box for making the cores *b*, Fig. 13 (*a*) and (*b*), is shown in the

three views, Fig. 14 (*e*), (*f*), and (*g*). It will be noticed that the pieces *a* and *b* are fastened into these core boxes to form openings for the stays or webs *o* and *n*, as in Fig. 13 (*a*); core prints *c* are provided to receive the ends of the cores *j* and *k*, Fig. 13 (*b*). In the case of the cores for both the inside and the outside of the arms, only half core boxes are necessary.

53. Core Box for the Outside of the Rim.—The core box for making the core *c*, Fig. 13 (*b*), for the outside of the rim is shown in Fig. 15. The box is very simple in construction, being composed of a simple rectangular box having perpendicular ends *a* and *b* and inclined sides *c* and *d*. The face *e* of the box is open, so that the core can readily be removed in this direction. The upper faces of the ends *a* and *b* are shaped to the same curve as the ends of the core *c*, Fig. 13 (*b*). There are also two ribs *f* and *g*, which are placed across the box at a sufficient distance apart to form the inside of the core. It will be noticed by reference to Fig. 13 (*b*) that the cores are longer than the width of the rim, and the distance from outside to outside on the ribs *f* and *g* is equal to the width of the rim, a proper allowance for shrinkage having been made. Instead of making the entire upper surface of the core box and ramming the core between it and the back plate on the ribs *f* and *g*, the sand between them is swept out by means of the strickle *h*, which runs on the ribs *f* and *g*. The core is all rammed from the upper or inner face, the central portion swept out with a strickle and then the core box lifted off, thus leaving the finished core on the core plate ready for drying.

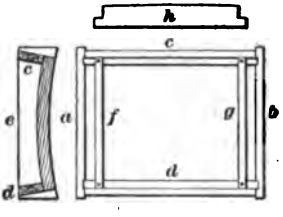

FIG. 15.

54. Core Boxes for the Hub.—The cores *i* and *k*, Fig. 13 (*b*), are made in ordinary circular core boxes or swept up upon iron arbors, and hence no description of the core boxes need be given. The cores *f* and *g* are made in

halves in the box shown in two views in Fig. 13 (*c*). The cores for making the bolt holes *p*, Fig. 13 (*b*), are supported in the recesses left by the core prints *a*, Fig. 13 (*c*). These bolt cores are made larger in the center so as to chamber out a portion of the hole and thus reduce the work necessary in drilling and reaming the holes and fitting the bolts. Making the cores *f* and *g* in halves greatly facilitates the placing of the cores for the bolts *p*, Fig. 13 (*b*).

55. Green Sand Work in Connection With the Mold.—The mass of green sand seen between the rim and cores *a* is rammed against the part pattern shown in place at *d*, Fig. 13 (*a*), and also shown in section at Fig. 13 (*d*). The inside rib *a* is not built up with the segment or part pattern, but is separate and screwed on after working off the inside of the segment, this being a much easier way than building the rib in the pattern. The two ribs *b* and *c* are also made separate and screwed on the segment after the body is completed.

The segmental pattern is made wider than the face of the wheel required, in order to make allowance for the ends of the core, as shown at *r*, Fig. 13 (*b*). The segmental pattern is held in place by two wooden arms *s*, Fig. 13 (*a*), and the lower portion of it is braced by suitable braces *t*, Fig. 13 (*d*). At the center of the mold, the arms *s* are attached to a center pin *u*, as shown in detail, Fig. 13 (*e*).

56. The segmental pattern is represented with the lug *v* for bolting the wheel together upon it. This lug is removed when ramming up the space between any two arms whose centers do not come on the joint line of the wheel. After the green sand portions *c* have all been rammed up, the cores *e*, Fig. 13 (*b*), are placed in position. The mold, if above the floor of the foundry, is surrounded with a ring of boiler iron, and green sand is rammed in back of the cores *e*. In some cases, the mold is built in the foundry floor and sand is simply rammed back of the cores *e* so as to fill the remainder of the pit. This wheel could also be made by building up the outside portion with brickwork

and sweeping loam upon it, instead of using the cores *e*, Fig. 13 (*b*). As the wheel is to be turned on the outside, it is not important that it should be smooth, and the method here illustrated is in many cases cheaper and more convenient.

57. In order to form a joint for the wheel, cast-iron plates, similar to those shown at Fig. 13 (*f*), are introduced into the joint to fill the space left by the core print *w* upon the segmental pattern. These plates have a series of holes in them through which the cores for the bolt holes are to be placed. The holes in the plates should be ½ inch or so larger than the cores for the bolt holes, so that some metal may flow through the holes and around the cores, thus giving an abutting surface surrounding each bolt. The hub of the wheel is also split by means of cast-iron plates, but no allowance is made in the case of the holes in these plates to have an abutting surface of metal about the cores for the bolts. All the venting from the cores in this mold is taken care of through the center cores *h* and *i*.

PATTERNS FOR SCREW PROPELLERS.

58. Development of the Curve for the Blades. In order to lay out the curve representing the pitch of a propeller screw, the following method may be used. If a cylinder were drawn with a diameter as shown in Fig. 16 (*a*), the diameter being equal to the distance across the points of the blades of the propeller and the line *a b* equal to the pitch of the screw, then the curved line joining these two points would represent the course of the blades if they were continuous. In order to determine the angle that these blades make, lay off *b c*, equal to the circumference of the cylinder, perpendicular to *a b*, and join the points *a* and *c*. The line *a c* will represent the length of the screw between *a* and *b*, and the angle at *e* will represent the angle that it makes at any point on the surface of the cylinder. If a piece of paper of the form *a b c* were cut out and wound around the cylinder, it would form the spiral shown and the point *c* would come

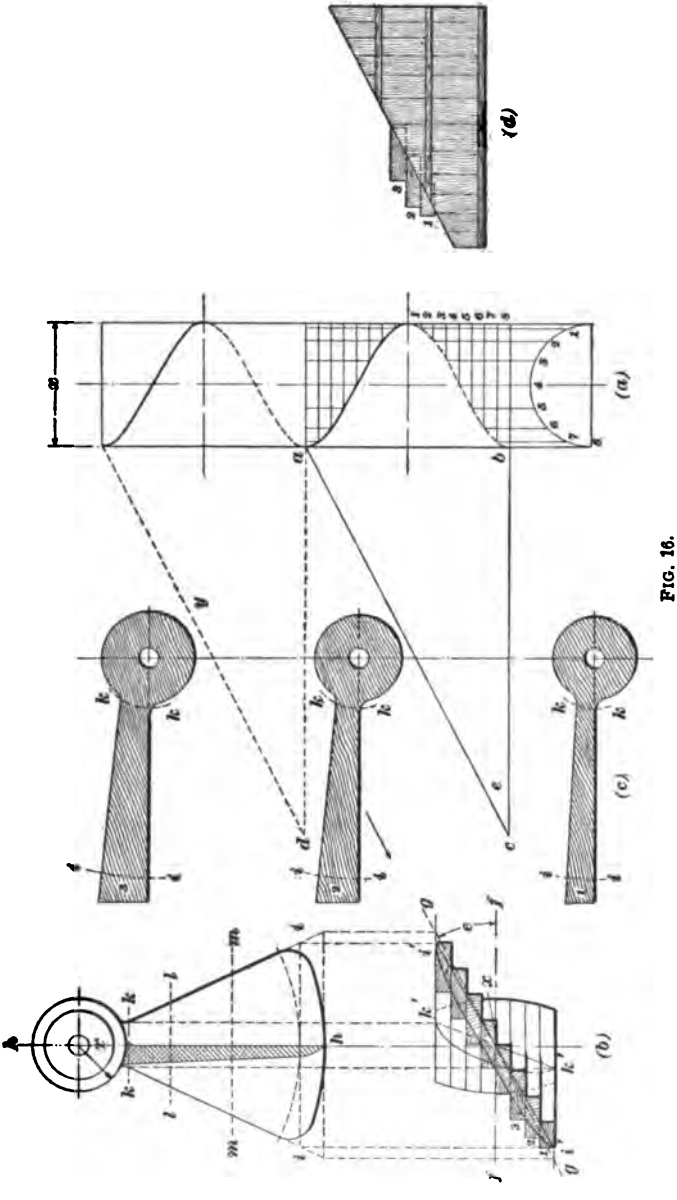

FIG. 16.

around to the point *b*. If it were desired to continue this spiral about the cylinder, other lines parallel to the line *a c* could be drawn as represented by the dotted line *y*, and, if this were wound around the cylinder, it would form a continuation of the spiral, the point *d* coming to the point *a*, etc., thus making a continuous thread. This method is the same as that used in laying out the threads on worms. The curved line representing the thread about the cylinder shown in Fig. 16 (*a*) is of no use in laying out the drawing, but has simply been projected for the purpose of illustration, the projected points being numbered the same in the half plan of the cylinder and in the elevation, so that the method of projecting may easily be understood. The angle at *e* that the outer end of the blade makes with the direction of its center line is the important point in the laying out of a screw propeller wheel.

59. Styles of Patterns.—Usually, a whole pattern is made for a small propeller wheel having three or four blades, as such a pattern saves much time in the molding, but when the pattern is 5 or 6 feet in diameter or is not liable to be used often, the molder can make a pattern for one blade answer the purpose for three or four by moving it around the spindle and ramming up the cope and drag in sections. The principles here given for building up one blade will also apply to a pattern having three or four blades.

60. Laying Out of the Blade.—Fig. 16 (*b*) shows one manner of laying out a propeller blade when there is no rake aft. Having obtained the angle of pitch *c*, Fig. 16 (*a*), it is an easy matter to transfer it to the blade. To accomplish this, draw the line *f f* across the center of the hub, and draw the line *g g* at an angle *e* with *f f*, the intersection being at the point *x* upon the vertical center line of the hub. Where the lines *f f* and *g g* intersect at *x* is the center of the blade represented by the line *h h* in the plan, and through this line the face must pass.

Having located the lines *h h* and *f f* and the angle *e* on the hub, the outline and longitudinal section of the blade are

laid out, the longitudinal section of the blade being shown cross-sectioned in the upper view and the outline of the end being shown in full lines intersecting the line *g g*. It will be noticed that the outline does not exactly coincide with the line *g g*. This is so because the ends *i i* recede from the line *g g* in order to conform to the surface of the cylinder and hence appear above and below the line *g g*.

The section on the line *h h* shows the actual thickness of the center of the blade lengthwise, while the outline on the line *i i* does not show the actual thickness, because it is projected. The shape of the outline of the blade is drawn on the pattern after it is built up. Different designers hold various opinions as to the best outline for a propeller, and the one chosen has simply been adopted for the sake of illustration.

61. To get the cross-section of the blade at the hub, the angle that the blade makes at the hub must be determined. This is done by drawing the lines from *k k* in the upper view until they cut the same upper or lower lines that *g g* do in the lower view, as shown at *k' k'*. Then *k' k'* will be the angle, but the intersection of the blade at *k k*, falling as it does on the round surface of the hub, will not appear straight as shown. It is drawn so in order to simplify the drawing, and, as it is intended for the patternmaker's working drawing, will answer all practical purposes. The cross-sections at *l l* and *m m* are omitted, but they may be obtained by projecting lines from the points at which these intersect the lines bounding the sides of the blade on to the lower view, and drawing diagonal lines similar to *k' k'*, upon which the sections may be drawn.

62. Building the Pattern. — Having obtained all the lines needed, the material for the pattern may be gotten out. Care must be taken to see that each course is parallel, for, if it is not, the building up will give trouble and cause the pitch to vary from that desired. In the lower view, Fig. 16 (*b*), it will be noted that the patternmaker is guided,

in forming the straight face of the blade, entirely by the positions of the corners of the segments as they are laid up, these segments being brought into contact with the line *i' i'*. For the sake of illustration, the material is cut as close to the line on the back of the blade as it is on the face, but there ought to be more stock allowed on the back than is represented in the drawing. In Fig. 16 (*c*) are illustrated the first three courses of the pattern numbered *1*, *2*, and *3*. The width of each course is determined by the end view, Fig. 16 (*b*), and the width at *k k* is obtained by drawing a circle on each course with a radius equal to *r* in the plan in Fig. 16 (*b*), and then transferring the different widths as seen at the section *k' k'* in the end view and adding enough stock to form the fillet at the hub.

63. In cutting out the courses, the grain of the wood should run as indicated by the arrow shown opposite segment *2* in Fig. 16 (*c*), as this will make the cutting and shaping of the blade much easier than if the material were sawed out with the grain running straight.

A wooden pin should be turned the same diameter as the spindle upon which the pattern is to be used and a hole bored in each segment to fit this pin. The courses of the blade are then slipped over the pin in their proper order, thus keeping all the courses parallel to one another, and at the same time permitting them to be swung to their proper positions.

Although each course may be of even thickness and the correct bevel laid off on the end of each piece, there is danger in the building up of the courses that they may lean over too much. To prevent this, it is a good plan to make an angle piece as shown in Fig. 16 (*d*). This angle piece is laid off with the same angle as that shown at *e*, Fig. 16 (*a*), and is used for a guide and support while building up the blade. The angle piece is built in the form of a cylinder, having a circumference equal to that of the periphery. Each course for the periphery of the blade is beveled off for a short distance in from the end so as

to rest on the incline of the angle piece, care being taken not to destroy the upper radial edge of each course in doing so.

After the courses are all placed in position and glued together, the straight face represented by *i' i'* on the outer edge and *k' k'* on the inner edge is worked off to the proper curves, the patternmaker being guided by the edges of the courses. When this is complete, the back of the blade is worked off to a templet, different templets having been made for several cross-sections, as, for instance, on the lines *l l* and *m m* in the plan shown in Fig. 16 (*b*).

While this pattern is shown built face down, with the ends of each course resting upon the angle piece, it may be built face up, and, by some patternmakers, the latter method is preferred, because it is plain that they can see better to guide the face edges right when they are on the upper side than when they are on the lower, but this is only a matter of individual preference.

64. Practically all propeller wheels are constructed with a slight rake aft, and this has to be taken into account in building a pattern. To allow for this rake it may be necessary to use one or more segments that do not extend to the hub or to cut away the hub end of some of the segments after they are in place. Propeller wheels are also frequently constructed which do not have a constant pitch. In this case the pitch is specified for certain points and the intermediate points are worked down so that the surface at one point blends into that at another without any sudden changes in form. To construct a pattern for a propeller wheel having a variable pitch, it is necessary to construct templets for several points at the face of the blade. Both in the case of propeller wheels having a constant pitch and in the case of those which have a variable pitch, some patternmakers construct a series of forms and build the pattern upon them. When this method is followed, a series of concentric circles are drawn on the board on which the pattern is to be built and the angle for the blade at each

one of these circles is calculated and a piece of metal cut out similar to the wooden form shown at Fig. 16 (*d*). Wooden guides are then sawed to the radius of the circles drawn and the metal forms fastened to these. The propeller wheel is then laid up, each succeeding segment being fitted against all the guides; after the pattern is built up, the material between the guides is worked off. This finishes the flat side of the propeller wheel. The form of the blade is then laid out upon this surface and the stock surrounding it cut away. In order to give the proper form for the other side, either one of two methods may be followed. In the first, a series of templets are made and the back of the blade worked down to these templets. In the second, the thickness of the blade at different points is calculated, small holes are bored through the blade at these points, and pegs are cut off to a length which will correspond to the thickness at these various points. These pegs are glued in the holes so that one end is flush with the flat side of the blade. After this the other side of the blade is worked off flush with the ends of the pegs.

65. Propeller wheels are also sometimes molded in loam, the lower face corresponding to *i' i'* and *k' k'* in Fig. 16 (*b*) being swept up with the aid of a guide similar to that shown at Fig. 16 (*d*). The blades are then built up from molding sand by means of templets, after which the cope is rammed. The cope is then lifted, the molding sand occupying the place of the blades cleared away, and the mold made ready for casting. When this method is followed, the casting is really obtained from a sand pattern. As this matter interests the molder more than the patternmaker, no further description of it will be given here.

FOUNDRY WORK.

(PART 1.)

INTRODUCTION.

1. Founding is a trade that involves some knowledge of almost every operation required in the making of machines; and men well versed in the mechanic arts assert that the art of founding demands greater mechanical skill, caution, and good judgment than any other of the allied trades. The art of founding is largely dependent on the hand and mind for results, machinery having played but a small part in the work of **molders** compared to what it has done for workers in most other trades.

There are three branches of **molding,** termed, respectively, *green-sand*, *dry-sand*, and *loam* molding. **Green-sand molding** involves the making of castings in molds that are composed entirely of sand in a damp state, or that have their surfaces "skin dried."

Dry-sand molding involves the making of castings in molds that are made with sand in a damp state, after which the sand is dried in an oven, or otherwise, so as to remove all moisture and leave the body of the mold dry and firm.

In **loam molding,** the castings are made in molds constructed with sweeps and skeletons of patterns; a mixture of loamy sand and other material is used to form the face of the mold, brickwork forming the outer and inner supports. This class of work, like dry-sand molding, requires thorough drying before the molds are cast.

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The practice of some shops embraces all three branches, but most foundries make only green-sand molds. There is generally more risk in making medium and large castings in green-sand molds than in dry-sand or loam molds. In many cases, a poor class of molders or inexperienced men may be employed for making dry-sand molds, but it is seldom wise to trust other than skilled workmen with the construction of green-sand molds, especially in heavy work. Loam work varies very much in the degree of skill required. Some classes of loam molds permit the employment of inferior workmen, while others demand extraordinary experience, skill, and good judgment in their production.

TERMS USED IN THE FOUNDRY.

2. The following are some of the most common terms used in founding:

Flask.—A flask is a frame or box that keeps the sand in place while the casting is being made. Flasks may be made of wood or metal. Wooden flasks are shown in Figs. 13 and 16, while an iron flask is shown in Figs. 14 and 15. A flask is composed of two or more parts. When composed of two parts, the one molded first, and which stands lowest while the mold is being poured, is called the **nowel** or **drag**, while the portion which is molded last, and which stands uppermost while the casting is being poured, is called the **cope.** When a flask has more than two parts, the portions between the cope and the nowel are called **intermediate parts** or **cheeks.**

Molding Board.—The molding board is the board or plate upon which the pattern is placed while ramming the sand into the nowel.

Bottom Board.—The bottom board is the board or plate which is placed on the top of the nowel before rolling it over, and hence it becomes the bottom of the mold during subsequent molding and casting operations.

Pattern.—A pattern is any form used in making a mold.

Sprue Pin.—A sprue pin is a wooden or metal pin used for making an opening through the cope through which the metal may be poured while pouring the casting.

Draw-Nail.—A draw-nail or **draw-spike** is a metal piece used in drawing a pattern from the mold.

Drawing and Rapping Plates.—Drawing and rapping plates are metal plates fastened upon patterns and intended to receive the ends of draw-nails or rapping irons. Frequently a draw-nail is threaded and screwed into a hole tapped in the draw-plate. The pattern may be loosened by rapping sidewise on the draw-nail, but it is better to use a rapping iron in a separate hole.

Gate.—A gate is an opening in the sand which connects the sprue with the opening left by the pattern. The term is also applied to the body of metal which occupies this passage after the casting has been poured.

Sprue.—A sprue is the opening left by a sprue pin and through which metal is introduced into the mold. The term is also applied to the metal which occupies the opening after the casting has been poured.

Riser.—A riser is an opening from the pattern to the face of the mold through which gas may escape and the surplus metal rise above the face of the casting.

Shake.—Shake is an allowance made on a pattern, on account of the fact that the mold is usually larger than the pattern, owing to the fact that the pattern has to be rapped sidewise in order to loosen it in the mold so that it may be removed, and the allowance necessary on account of this increase in size is called an allowance for shake. Such an allowance is made only on patterns under 4 inches in cross-section.

Draft.—Draft is a term used to denote an allowance which results in the increase of certain dimensions of the pattern so that the face may be the largest cross-section of the pattern and that all surfaces tending from the face may form an angle of less than 90° with it. An allowance for

draft is made to facilitate the withdrawing of the pattern from the mold.

Molding Sand.—Molding sand is composed of a mixture of sharp sand with a certain amount of clay and the term is used to cover a large variety of sand employed in the different branches of green-sand molding. Sand is said to be **sharp** when its individual grains are angular, and **dull** when its individual grains are round. Sand is said to be **strong** when a body of it manifests a disposition to retain any shape that may be given to it, and **weak** when it tends to fall apart and will not retain a given shape. Other things being equal, the sharper the sand the stronger it is; but the sharpest sand is weak without some cementing admixture, as clay. If molding sand is too sharp it will not hold its shape, and if too strong it will not permit the gases to escape through it during the casting.

Parting Sand.—Parting sand is a general term applied to any material used to prevent two surfaces of a mold from adhering. It is usually made from sharp or burned sand.

Fireclay.—Fireclay is a clay capable of withstanding intense heat. It is used for lining ladles, to line cupolas, and in places where great heat must be resisted. It is also used as a clay wash for strengthening molding sand.

Facing.—Facing is a general term applied to any material used for lining the walls of a mold, for the purpose of improving the finishing of a casting.

Rammer.—A rammer is a tool used for tamping the sand in the mold. There are two classes of rammers, called **hand rammers,** which are used for light molding and are only 16 to 20 inches in length, and **floor rammers,** which are intended for heavy ramming and are usually several feet in length. In Figs. 14 and 15 the floor rammer is shown in use. One end of the rammer has a flat rectangular point called a **peen,** as shown at *c*, Fig. 13, and the other end a large flat surface called a **butt,** as shown at *d*, Fig. 13.

Sieve.—A sieve is a tool used for sifting sand or for removing coarse material from the sand. The hand sieve

is composed of a circular frame, the bottom of which is covered with wire cloth.

Riddle.—The riddle is a coarse sieve.

Trowels.—There are a large number of forms of trowels used in molding and they will be illustrated in connection with the work upon which they are required.

Slickers.—Slickers are small trowels or trowel-like tools used for finishing the face of molds and will be illustrated in connection with the work on which they are required.

Gaters.—Gaters are small trowels or bent pieces of sheet metal employed for cutting the gates from the bottom of the sprue to the casting.

Vent.—A vent is any opening in a mold provided for the escape of gas or steam.

Vent Wire.—A vent wire is a small rod or wire used for forming a vent.

GREEN-SAND MOLDING.

3. Grades of Sand.—The sand for making **green-sand molds** should vary in its physical qualities according as the castings to be made are light or heavy. For light castings the sand should be of a fine grain, while heavy castings require sands that are of an open, coarse-grained texture. If the sands that are best fitted for heavy work are used in making light work, the castings will have a rough skin, or surface. If the fine sands suitable for light castings are used for making heavy ones, there will be great danger of creating **scabs,** or causing the castings to **blow,** on account of the sand being so fine in texture that it will not allow the gases (created at the face of the mold by heavy bodies of molten metal) to escape freely through the sand and vent holes of the flasks.

4. Chemical and Physical Character of Sand.—Sand varies more in its physical properties than in its chemical composition. The chief constituent of sand is silica,

though it also contains alumina, lime, iron oxide, together with other elements that may be present in some grades of sand and absent in others. Chemical analysis has thus far rendered but little aid to persons in the selection of different grades of sand.

5. Where Molding Sand Is Found. — Molding sand suitable for medium-weight and heavy green-sand castings is found in almost every part of the United States. Sand for light work is the most difficult to obtain; many light-work foundries are compelled to rely wholly on the fine sand found in and around Albany, New York. This sand makes the finest light-work castings produced in the country. It is good for brass molding as well as iron.

PREPARING THE SAND.

TEMPERING THE SAND.

6. Meaning of Term. — In mixing or **tempering** sand by hand, the shovel should be used in such a manner as to scatter the sand, as shown in Figs. 1 and 2. This is done by giving the shovel a twist with the hand that holds the handle end. When shoveling sand from one place to another without attempting to mix it, the sand is sometimes allowed to leave the shovel in a solid mass, as shown in Fig. 3. This method of shoveling permits of throwing the sand to a greater distance, and, hence, is used when shoveling sand from place to place, as from a car to a bin.

FIG. 1.

A molder or helper should learn to shovel either right- or left-handed, so as to be able to take either side of a sand

FIG. 2.

heap when working with an assistant; note the different relative positions of the two men in Figs. 2 and 4. A clear

FIG. 3.

space of from 1 to 2 feet should be maintained between the pile from which the sand is being shoveled and that upon

FIG. 4.

which it is thrown, as in Figs. 3 and 4. If this is not done, much of the sand will escape thorough mixing.

7. Shovels.—In Fig. 5 are shown the two kinds of **shovel** in general use, (*a*) having a flat blade, while (*b*) has

FIG. 5.

turned edges. The flat shovel is generally used for light floor work and bench molding, while shovel (*b*) is used for heavy molding and digging out holes.

A molder should never work with a dirty shovel. When in use the shovel should be kept clean by scraping as shown in Fig. 6. When put away for the night, or if not in constant use, a shovel should be cleaned of all

dirt and oiled with a greasy rag to prevent its getting rusty. There is nothing that denotes the poor or slovenly molder more than working with a dirty shovel.

FIG. 6.

8. Wetting Down the Sand.—In throwing water on a sand pile with a bucket or hose, it should never be thrown in a body on one spot, as that will form mud-holes and involve a loss of time and labor in mixing the mud with drier sand in order to temper it. If the sand is very dry, water should be sprinkled upon it from a hose, or by being thrown from a bucket as in Fig. 7. When the sand has been dampened nearly to its right temper, so as to require but little

FIG. 7.

more wetting, it should be sprinkled by hand from the bucket, as shown in Fig. 8.

FIG. 8.

9. Sieves and Riddles.—The meshes or openings of a **sieve** range from the fineness of a flour sieve up to openings $\frac{1}{8}$ inch square; when the openings are above $\frac{1}{8}$ inch square, the implement is called a **riddle.** In Fig. 9, (*a*) shows a sieve and (*b*) a riddle. In sieving or riddling sand by hand, the riddle should not be held rigidly, as shown in Fig. 10, but should be held loosely, so that the butt of the hand can strike, or jar, the rim of the riddle as it is swung from one side to the other, after the manner shown in Fig. 11. Hitting the

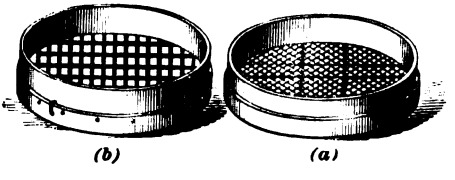

FIG. 9.

rim of the riddle or sieve with the butt of the hand causes a jar over the whole face of the meshes, and this causes the

FIG. 10.

sand to pass through the meshes much more freely than if the tool were held rigidly, as in Fig. 10.

FIG. 11.

When sieves or riddles are not in use, they should not be thrown on the damp ground or on a sand pile with the mesh side down, as such a practice will clog the meshes with sand in such a manner as to hinder the passage of sand through the screen and also cause the wires to rust away very rapidly; they should be placed either on the sand heap with the mesh side up, or else hung upon a nail, as in Fig. 12. A skilled molder can be detected by the way he handles his sieve and riddle, as well as his shovel.

FIG. 12.

PREPARING THE MOLD BY "ROLLING OVER."

FLASKS.

10. Flasks are open frames of wood or iron, usually consisting of two parts, though sometimes of three or more, so arranged that they may be taken apart and then returned to exactly the same relative positions that they had before they were separated. For this purpose they are provided with special projecting pins and sockets. They have two loose covers, called a "top board" and a "bottom board." When there are two frames (the **cope** and the **nowel**) to the flask, it is called a "two-part flask"; when three frames, a "three-part flask"; and so on, for four or more. There is a great variety in the shapes and sizes of flasks; the molder usually takes the smallest flask in which he can safely make the mold for any given casting. The most common form of wooden flask is that shown in Figs. 16 and 35. There is,

also, a special type known as a "snap flask"; this opens at one corner and has a hinge on the opposite corner, so that the flask may be removed from a mold, after the mold is completed, and used over again before the mold is poured.

RAMMING THE MOLD.

11. Fig. 13 (*a*) represents the **ramming up** of a deep pattern *P*. The depth of the ramming courses varies from

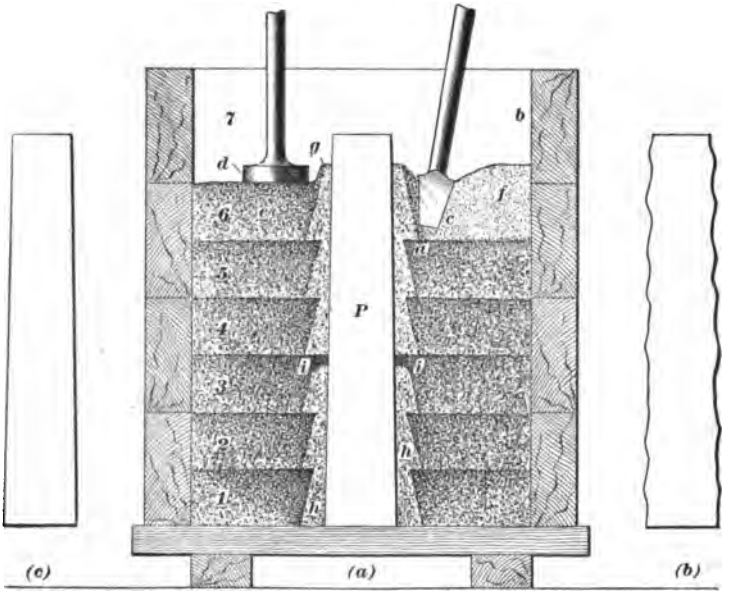

FIG. 13.

4 to 8 inches, according to the strength of the molder and the character of the work he has in hand. For the pattern shown, a depth of 5 to 6 inches of loose sand will work well in the ordinary molder's hands. In starting to learn how to use the **floor rammer,** beginners generally handle it in the manner shown in Fig. 14, which is wrong; the proper way to handle it is illustrated in Fig. 15. In starting to

ram a course of sand, the **peen** end is used first and should be struck down with sufficient force to feel a solid bottom; this bottom may be either the mold board *c*, Fig. 15, or it may be the course of sand that has just been rammed, as *5* in Fig. 13, where the peen end of the rammer is shown at *e* and the rammed sand of the previous course at *a*. In ramming the space between the pattern and the inside of the

FIG. 14.

FIG. 15.

flask *b*, the peen is first carried along the face of the pattern, as seen at *c* in the illustration, and then used promiscuously over the remainder of the space until it has been rammed down fairly well with the peen; then the rammer is reversed and the **butt** *d* used over all the surface.

After the butt has been used to ram down a course of sand 5 or 6 inches thick, it leaves that course from 1 inch to 1½ inches lower than when finished by the peen, as will be seen by comparing the portions *e* and *f* of course *6*, Fig. 13. The mound seen at *g*, Figs. 13 and 16, is then rammed down lightly with the peen. After this, the hand is used, as shown

on the right of Fig. 16, to level down and clean away the "facing sand" lying against the pattern (which is liable to have **common heap sand** mixed with it), to prepare for another course of facing and ramming. In using the rammer for the first peening and the butting, care should be exercised to keep the peen and butt about 1 inch from the face of the pattern during the ramming, as when driving the peen down, it is liable, if forced up against the pattern, to make a hard spot in the face of the mold that may cause a scab on the face of the casting at that point. If the courses of sand are not rammed evenly, after the manner just described, the castings are very liable to be badly swelled at the line of union of the courses, and thus appear as shown at (*b*), Fig. 13; whereas, if the courses of sand are rammed evenly, the casting should appear as shown at (*c*).

FIG. 16.

In starting on a mold, the patterns should be faced with a proper **facing sand** that has passed through a No. 8 sieve, so as to have an even surface on the face of the mold. The facing sand is applied to the face of the pattern for a thickness of from 1 to 1½ inches, as at *h*, *h* in Fig. 13. After this facing sand has been banked against the face of the pattern, common heap sand is filled in to the level of the facing sand, and the whole is then rammed down with the peen and butt of the rammer. In banking facing sand against a pattern, it should be carried as high as the common sand is intended to go. If this is not done, the result will be a seam of common sand, as at *i*, Fig. 13, separating the

parts of the facing against the pattern *P*. If the facing sand is not thoroughly united at the seams of each course of ramming, the castings will be rough and often will have "burned sand swells" at the seams of all such course of ramming. This will make a casting look almost as bad as do swells caused by uneven ramming, as seen in view (*b*), Fig. 13.

12. Hardness Required in Molds.—As a rule the sand on the sides of molds will stand harder ramming than that on the bottom or the top; and again, the deeper the mold, the harder the ramming required at the lower courses. As an example, in ramming the mold shown in Fig. 13 (which is rolled over when rammed full), the courses *5*, *6*, and *7* will require harder ramming than the courses *1*, *2*, *3*, and *4*, on account of the static pressure of the metal, when the mold is being poured, being greater near the bottom. Molten metal behaves like water in this respect; if we fill a barrel with water, there is greater pressure on the sides near the bottom than near the top. A barrel may be filled with water without bursting at the bottom; but if we insert a pipe about 15 feet long into a barrel closed at both ends, and then fill this pipe with water, the barrel may burst, unless it is very strong. It is the same with molds; the deeper they are, the harder should the sand be rammed and its support strengthened to prevent the static pressure of the metal bursting the bottom of the mold and letting the metal run out. The extra degree of hardness at the bottom portion of the mold, as compared with that near the top, depends on the power and time applied in ramming with the butt of the rammer. The face of the mold should not differ very much in hardness at any point in the height of the mold. This evenness is obtained by treating the mold with the peen in the same manner at the bottom as at the top. If the mold is very high, the lower portion should be rammed a little the harder. By keeping the edge of the butt of the rammer back about 1 inch from the face of the pattern, as explained in Art. **11**, some pretty hard

butt-ramming can be given to the common sand backing the facing sand without getting the face of the bottom portion of the mold so hard that the metal will not lie against it. By butt-ramming all the surface, up to a point about 1 inch from the face of the pattern, until it is hard, it is possible to make the entire face of the mold harder than if lighter butt-ramming was done close to the face of the pattern. Nevertheless, this plan will not make the face of the mold as hard as if greater force were also applied to the peen when ramming. Castings having a depth of 4 or 5 feet have been made in green-sand molds; at these depths the back support of the molds must be very rigid and the ramming nearly as solid as it can be made with the butt. Were the upper portions of such molds rammed as hard as the bottom must be, the castings would blow and scab.

The reason why the lower portion of a mold will permit so much harder ramming than the top portion is that the greater pressure of the metal at the lower portion forces the steam and gases to escape through the pores and venting of the sand. At the top of the mold there is not sufficient pressure to do this. If a mold is not sufficiently soft at its upper end to allow the steam and gases formed at the face of the casting to escape freely through the facing sand to the rear sand and its vents, they will pass out through the metal. When steam and gases escape in this manner, they are liable to cause a mold to blow. This may result in scabbing a casting or in spoiling it. It should always be remembered that steam and gases will pass off where they meet with the least resistance.

DEEP MOLDS.

13. Dry Sand Required.—While it is true that the lower part of deep molds requires hard ramming to prevent the molds from bursting or being changed materially from the size of the pattern, there are conditions other than that involved in the ramming that must be provided for and

controlled. In using facing sand as well as in using common heap sand in ramming deep molds, the sand must be worked as dry as possible, and must be freely vented. If the damp sand that can be safely used on the sides of shallow molds were used to ram up deep molds, and rammed as hard as it should be, the chances are that the moment the metal flowed into the deep molds, they would commence to blow and send the metal to the roof, spoiling the casting and probably burning the workmen standing near by. The sides of a mold may be rammed much harder if the sand is comparatively dry than if it is wet. The reason for this is explained later on.

14. Venting the Mold.—The sides of all deep green-sand molds must be well **vented.** The harder the ramming, or the damper the sand is, the greater is the amount

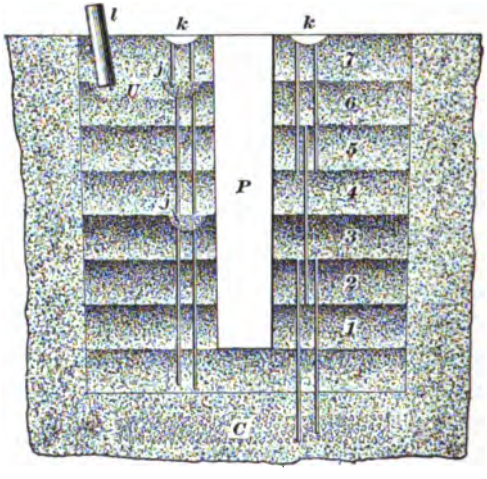

FIG. 17.

of venting required. There are several methods used in providing these necessary vents. Suppose the pattern in Fig. 17 to be **bedded in** instead of **rolled over,** as was done in Fig. 13. In ramming the mold, the same plan is followed as in Fig. 13, the only difference being that the courses *1*, *2*, and *3* are rammed the hardest, being the

ones that must stand the greatest strain; whereas, the courses *1*, *2*, and *3*, in Fig. 13, being the uppermost when cast, are rammed the lightest.

In ramming up the pattern by "bedding in," Fig. 17, the sides can be vented in the following manner: After three to four courses have been rammed, a channel or groove is cut out of the solid rammed sand, as shown by the letter *j* in the course marked *3*, Figs. 17 and 18. This done, the channel is vented with two rows of ¼-inch **vents.** These vents are put in 2 inches apart and are kept back about 2 inches from the face of the pattern; their position is shown by the rods seen projecting from the sand at *j*, Fig. 19, in which illustration the molder is shown in the act of venting with a **vent wire.** Two rows of vent holes are shown. These are used in cases where extra good venting is required, as when the sand is of a fine, close grain and has to be rammed hard, or when it is wet. When the sand is fairly open in texture, or when hard ramming is not necessary, and the sand is not too wet, one row of vents will be sufficient. After the venting has been done, the **vent channel** at *j* is filled with cinders, the pattern is again banked with facing sand, and common sand then filled in for backing. This course is rammed up in the usual manner, and so on until two more courses are completed, when another vent channel, as shown at *j* in the course marked *6*, Fig. 17, is made and vented as above described. These courses of vents may be repeated any number of times until the top of the pattern is reached. Some molders lead the gases from these vent channels *j* into straight vent channels *k* at the joint of the mold. This is a bad plan, for if there is any breaking of joints by **drawing** the pattern or from a **straining** of the cope, allowing large **fins** or a

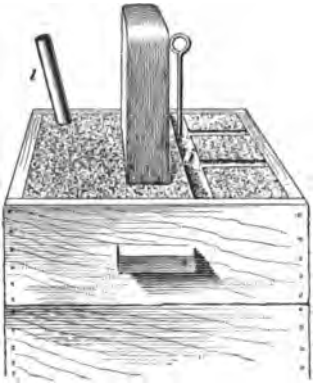

FIG. 18.

run out, the metal will run into the vent channels at *k* and fill them with iron; this may cause the loss of a casting by scabbing or blowing. In most cases of deep-sided molds, it is best to lead the gases from courses of cinder vents up to the joint by separate outlets, made by ramming up gate

FIG. 19.

sticks in a mold, as seen at *l*, Figs. 17 and 18. These openings should be placed as far as possible from the face of the pattern and provision made for conducting the gases to them, as shown by the channel *U*, Fig. 17. To insure the best possible venting, the molder vents each course as it is rammed with a $\frac{1}{8}$-inch wire. These fine vents will give relief to the gases working through the sand to the large,

or ¼-inch, vents shown leading to the channels *j*. Should these ⅛-inch vents meet the pattern, the iron will not run into them and do damage as it would if the vents were ¼ inch.

15. Where the sand can be worked fairly dry, or where it is of a very open texture so as to permit the gases to penetrate for a considerable distance, the method of venting illustrated on the right of Fig. 17 can be used with safety. This plan consists merely in using a ¼-inch vent wire, keeping it about 2 inches away from the face of the pattern, with the vents about 2 inches apart. In using the vent wire it should be passed through the last two courses laid, and half way through the one under them. This is repeated at every other ramming until the joint on top of the mold is reached. In some cases a ⅛-inch vent wire is used after ramming every course and the ¼-inch vent wire after every other course, as described above. In case there is a **cinder bed** *C* under the mold, the vents may be made to connect with that bed, Fig. 17, as well as carried to the top joint.

16. Where difficulty is experienced in venting deep molds or long horizontal green-sand cores, the venting may be done in the following manner: Instead of using the ordinary vent wire or rod, which is difficult to remove if long, and which cannot be removed if at all crooked, a vent rod is made by pushing a braided sash cord through a piece of rubber tubing and inserting the tube instead of the rod when making the core or mold. The act of forcing the braided cord through the tube pushes the cord together, making it somewhat thicker, which in turn expands the tubing and makes it practically solid. When this vent rod is to be removed it is done by first pulling out the sash cord, which allows the tube to contract so that it may be easily removed. Vents made in this manner may be carried long distances and even around considerable bends that could not be dealt with by ordinary methods. The labor of pushing the sash cord through the tubing may be materially reduced by pouring a handful of fine graphite through the

tubing before entering the cord, and, also, rubbing the cord with the same.

17. Venting Shallower Molds.—Where molds are not over 20 inches deep, vents may be driven straight from the joint after the cope has been lifted, as shown by the vent wire in Fig. 18. This avoids any venting while ramming the courses. If there is a cinder bed under the pattern, the vents should be carried downwards to the cinders, and the top outlets *k*, Fig. 17, can be stopped up or dispensed with. This is a good scheme where there is any liability of the pattern breaking the joint and leaving a fin while being drawn, or any danger of the cope straining so as to let iron run into the vents when they are left open.

18. Using a Slanting Vent Wire.—In venting directly from the joint, care must be taken not to let large vent wires that are driven in a slanting direction strike the pattern, as does vent *v* in Fig. 20, leaving a sharp point of sand at *a*, for this may cause a slight blow at that point and burst the vent hole inwardly, and thus cause a flaw that may spoil the casting. Such slanting vents are apt to fill with iron and cause scabs, or, worse still, cause a mold to start blowing. A mold would be far better without a vent in it than to have a lot of vents like those in Fig. 19 filled with iron, as in such a case they only help to create gas.

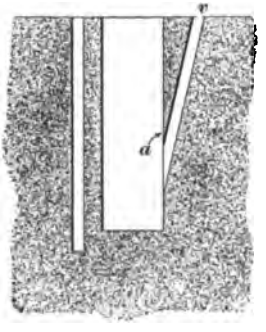

FIG. 20.

19. Cinders for Vent Channels.—In obtaining **fine cinders** for filling such vent channels as those seen at *j*, Figs. 17 and 19, the following plan is generally adopted: Cinders from an ash or coke pile are first placed in a ½-inch riddle that is shaken to get the fine cinders and dust separated from the coarse material. The stuff that stays in the riddle is thrown away and what has passed through is again riddled through a ¼-inch riddle. What passes through this

second riddle is thrown away and what stays in it are the cinders that are used for filling the vent channels at *j*. In obtaining such cinders, the two riddles can, if desired, be attached together and used at the same time, each being emptied when full. The cinders thus obtained will be of a uniform and clean character.

EXAMPLE ILLUSTRATING DEEP MOLDING.

20. The Pattern.—The pattern shown in Fig. 21 illustrates a number of points that should be observed in deep molding, and would be an excellent example for a beginner to practice on. This pattern gives sufficient depth for three courses of ramming, and will afford good practice in learning to ram evenly. This pattern can be molded in a flask and then rolled over, as in Fig. 13, or it can be bedded in, as in Fig. 17. The pattern is made with a good taper to facilitate its being drawn from the sand. This taper or reduction in size of the pattern as it recedes from the face is called **draft.** For convenience in handling the pattern while drawing it from the sand, iron draw-pieces, called draw-irons, may be screwed to the pattern, as shown at *a*. The purpose of groove *b* is to allow the casting to be easily broken; this groove provides a little irregularity in the pattern that will the more thoroughly test one's ability to ram evenly.

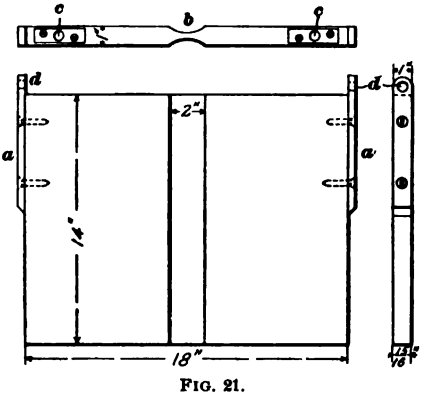

FIG. 21.

21. Making the Nowel.—The principles involved in ramming and venting the sides of deep patterns have been

described and illustrated in Arts. **10** to **19,** and so the detail of ramming up the nowel will be omitted. Fig. 22

FIG. 22.

shows the nowel rammed up, the bottom board bedded on solidly, and all clamped together ready to roll over. Fig. 23

FIG. 23.

shows the flask rolled over, the molding board removed, and the molder making the joint by **sleeking** it over firmly

with a trowel. After the joint is thoroughly sleeked so as to give the sand a fine finish, a brush is used to free the surface of all dust.

22. Parting Sand.—The joints having been thus finished, **parting sand** is shaken from the hand, as seen in Fig. 24, in such a manner as to distribute it evenly over the joint. The use of parting sand is to cover the joint with some

FIG. 24.

material that is not adhesive, so that when it is spread between the bodies of damp sand, it will allow them to separate, without pieces of one body adhering to the other. Material for making parting sand is generally obtained in foundries from the fine dry sand that sticks to the surface of castings before they are cleaned. All the clay contained in this sand has been burned hard, and for this reason when placed between two damp bodies of green sand it will prevent their sticking together. Another kind of parting sand is obtained by using fine grades of lake, river, or seashore sands that have been dried on a plate over a hot fire. Before using this shore sand or the dry burned sand from castings, it is

passed through a sieve as fine as can be used—in some cases a flour sieve.

23. Ramming the Cope.—After the joint is made and covered with parting sand, the cope is put on and the pins or patterns for forming the gates are set ready for ramming, as shown at *e* and *f*, Fig. 25. While ramming the nowel, the pattern *g* for the horn gate was put in place, as shown in Fig. 25. This form of gate is used to introduce the metal near the bottom of the mold. Before the cope is put on, its bars, *1*, *2*, and *3*, are thoroughly wetted with

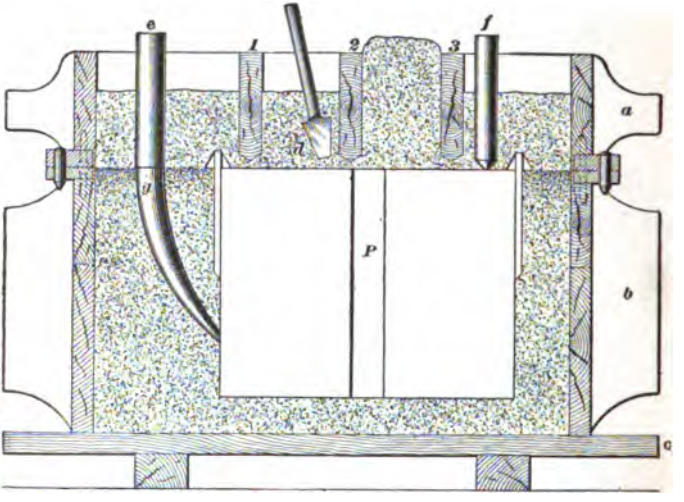

FIG. 25.

water, to make the sand stick to them. If the sand is not of such a loamy nature as to hang well, a clay or loam wash or a thin flour paste is often used instead of water on the face and sides of the bars. After the cope is in place, a facing of molding sand is then sieved over the joints to a depth of from $\frac{3}{16}$ to $\frac{1}{4}$ inch. After this, a riddle is used in filling the cope to a depth of about 2 inches. This operation is followed by tucking the sand under the bars with the fingers of each hand, until the sand is as solid as the fingers can ram it. Unriddled sand is then filled into the cope to

the level of the top of the bars. The peen end of the rammer is now used to ram the sand firmly between the various bars, which will pack the sand to about the level seen between bars *1* and *2*. It is very important to peen the first course thoroughly, for if this is not done, there are liable to be soft spots in the face of the mold under the bars; or the sand at the bottom of the bars may be so soft as to drop out when lifting off or closing the cope. After the first course of sand is thus peened between all the bars, more common sand is filled in and heaped above the level of the bars, as seen between *2* and *3*. This done, the peen is again used to ram the second course of sand between all the bars. Less care and time can be spent on peening this second course, because the butt of the rammer is to follow the second peening. In peening the first course, the peen should be directed in such a way as to pack the sand under the bars, as seen at *d*. When both courses have been peened, the butt of the rammer is used to ram down the mounds of sand between the bars, as between *2* and *3*. The butt is struck down solidly to pack the sand between the bars. With the first course it is important that it be firmly peened to keep it from dropping out, and this is also true as regards the butting, for if that is not done firmly, the cope is liable to drop out.

In ramming the cope, care must be taken not to strike the bars, as that might loosen the sand and cause it to drop out when lifting off the cope or closing the mold. After the cope has been rammed, any excess of sand is removed by striking off the top of the mold with a piece of board or with the handle of the floor rammer. The mold is then vented with a $\frac{1}{8}$-inch wire, the vents being about 2 inches apart all over the area covered by the pattern. This done, the sprue pin *e* in the pouring gate and riser pin *f* are withdrawn. Then the tops of both gate and riser are reamed out funnel shaped, and all loose sand firmly tamped down with the fingers and then dampened lightly with the swab, so that in pouring the metal, it cannot wash any dry dust or sand into the mold along with it. The mold is now

ready to have the cope lifted off, which is done, and the cope placed on any suitable support, as the box shown in Fig. 26.

24. Venting the Nowel.—After the cope is lifted off, the parting sand is carefully brushed off the joint, and the joint "swabbed," care being taken not to get too much water on it around the edges of the pattern. This done, a ¼-inch vent wire is used to vent the sides opposite the places

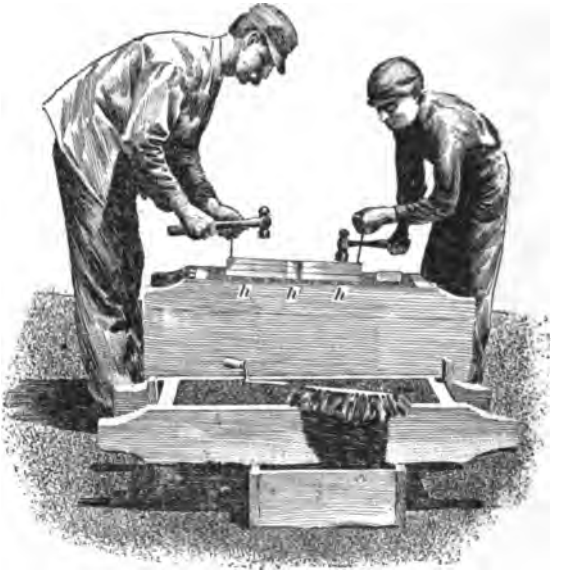

FIG. 26.

marked *h*, *h* in Fig. 26, and a groove is run from each vent to the outside of the mold. It will be noticed that this method of leading away the gases from the joint differs from that illustrated in Fig. 18.

In the case of molds having joints that are liable to be broken in drawing the pattern, the method of venting just described should be used, because if the iron should get in the joint at any one point of a vent channel, as at *k*, Fig. 17, it might readily fill all the vent holes.

25. Drawing the Pattern and Finishing the Mold.—After the mold is vented, the pattern is loosened

by **rapping.** This is accomplished by placing a pointed iron bar in the **rapping holes** shown at *c*, *c*, Fig. 21, and rapping it with an iron bar or a hammer. This done, lifting hooks are placed in the holes *d* of the draw-irons and two men gradually start the pattern, each of them holding a lifting hook in one hand and in the other a hammer, with which they tap the pattern lightly on the draw-plates *e*, Fig. 21. Care must then be taken to bring the pattern up steadily until it is out of the mold. After the pattern has been drawn out, the horn gate *g*, Fig. 25, is drawn. The trowel is next used to press down any portion of the joint that may have been started in drawing the pattern, to smooth up the cope part of the mold. The top of the pouring gate and riser are then reamed out funnel shaped. Should any dirt have fallen into the mold, a **lifter** [see Fig. 41 (*c*)] is passed into the mold and the dirt removed.

26. Closing and Casting the Mold.—The mold is now closed and clamped with two **clamps,** as shown at *i* and *j*, Fig. 27. It is now ready for casting, which is done by two men holding the ladle and pouring the mold, while a third one is skimming. Molten iron always contains more or less scum or dirt, which, if allowed to pass into the casting, will make flaws that will impair its strength and finish, and may even cause its loss. For this reason when

FIG. 27.

molten iron is being poured from a ladle, a skimmer should always be used to hold back the dirt.

27. Shaking Out the Casting.—About 30 minutes after the casting has been poured, it can be **shaken out,** which means that the cope may be taken off the nowel and the nowel itself removed from the mold, care being taken not to disturb the sand about the casting. After some hours the casting may be removed from the sand, when, with the gate and risers attached, it will appear as in Fig. 28. The horn gate is shown at *g*, the straight portion of the gate at *e*, and the riser at *f*. The pouring-gate horn can be freed from the casting with a fair blow of a hammer held as shown in Fig. 44. When the gates are removed and the casting cleaned, the job is finished. By measuring the thickness of the casting at the top and bottom and comparing the difference with the difference existing in the pattern, the maker can tell how near his ramming came to preventing any distortion of the casting due to the pressure of the metal in the mold.

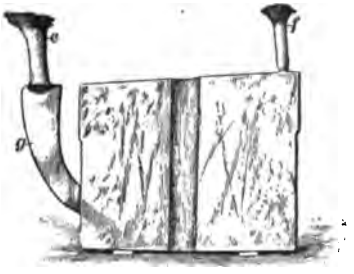

FIG. 28.

ALLOWANCE IN PATTERN FOR DISTORTION.

28. While it is true that hard ramming tends to decrease the amount of distortion that occurs in the lower part of deep molds, it is nevertheless impracticable to ram very deep molds hard enough to prevent more or less distortion. Few experienced molders ram alike, and so some produce castings more distorted than others. No definite rule can be given for the allowance to be made for distortion in deep castings due to the straining of the mold on account of the great pressure in the lower part of the mold. In the case of experienced molders who are recognized as hard

rammers, an allowance of $\frac{1}{32}$ of an inch per foot would be sufficient, while equally experienced men who do not ram their molds as hard might require an allowance of $\frac{1}{16}$ of an inch per foot. In the case of a pattern 5 feet deep, if an allowance of $\frac{1}{16}$ inch per foot were made it would decrease the dimension of the pattern at the bottom of the mold $\frac{5}{16}$ of an inch. From this it will be seen that the allowance for distortion tends to give draft to the pattern. Where the conditions are all known, it is possible to produce practically parallel castings from a tapered pattern, the distortion due to the straining of the lower portion of the mold just neutralizing the amount of draft necessary on the pattern.

SHALLOW MOLDS.

29. Ramming a Flat Surface.—The molding and casting of a square, flat plate, about 10 inches square and 1 inch thick, is illustrated and described in Arts. **29** to **35.** In ramming flat or plate surfaces like the pattern

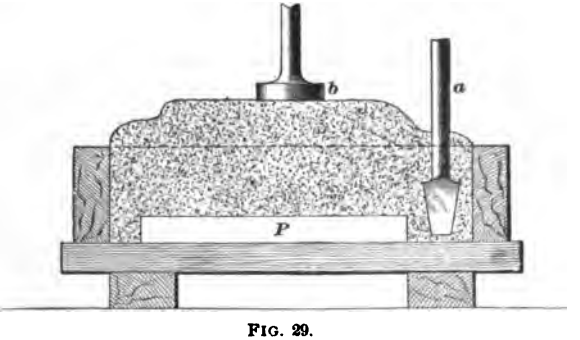

FIG. 29.

shown at *P*, Fig. 29, the peen *a* should never be used over the face of the pattern during the ramming of the first course; if this is done, it causes uneven ramming and may make hard spots in the mold, and so cause scabs or indentations that may spoil the casting. In the case of flat or plate work, the sand is rammed up in courses from 4 to 5 inches thick. The operation of **striking off** the nowel is

shown in Fig. 30. The sand having been struck off as shown, the hand is then used to sprinkle molding sand to the depth

FIG. 30.

FIG. 31.

of about $\frac{1}{4}$ inch all over the surface of the struck-off sand, as in Fig. 31. This is done to allow the bottom board to be rubbed down to a solid bearing when in place, as in Fig. 32.

FIG. 32.

FIG. 33.

30. Venting the Nowel:—After the bottom board has been bedded on solidly it is taken off again and a rod, rammer, or strike is used to form creases or indentations in the sand, as shown at *a*, Fig. 33. These creases are placed

about 1½ inches apart and permit the gases from the ⅛-inch under vents to escape along the face of the bottom board when the mold is being poured. The vent passages having been made, as at *a*, a ⅛-inch vent wire is then used, in the manner shown at *b*, to vent the nowel all over the surface covering the pattern. The vent wire should not be driven down until it strikes the pattern; if it comes within ⅛ inch of the face of the pattern, it is sufficient. The entire area over the pattern having been vented, the bottom board is replaced and clamped, so that the nowel may be rolled over, as shown in Fig. 34.

FIG. 34.

31. Venting the Cope.—The nowel being rolled over, the joint is prepared as described in Arts. **21** and **22.** The cope is then put on and the sprue pins for forming the pouring gate and riser set in place, as shown at *e* and *f*, Fig. 35. After this, sand is sifted on to the face of the pattern to a depth of about ¼ inch; the cope is filled with heap sand, rammed as described in Art. **23,** and vented over the part above the pattern with a ⅛-inch vent wire. It is then lifted off and finished with a trowel ready for closing.

FIG. 35.

32. Swabs and Swabbing. — The cope having been finished, the joint is brushed off and dampened with

the **swab** shown in Fig. 36 (*a*). The swab is dipped in water and then lightly squeezed out, after which it is passed over the joint as shown in Fig. 37, care being taken not to get the sand too wet along the joint between the pattern and sand. Where delicate swabbing is required, as in bench molding, or the wetting of small bodies of sand, a sponge with a wire or long thin nail passed through it, Fig. 36 (*b*), is often used in the manner shown in Fig. 38. The sponge holds the water until squeezed out with the hand, and the wire or nail directs the water to the spot to be dampened. In making the swab shown at (*a*), a piece of fine grade long-fiber hemp rope is tied at one end with a fine wire or string to form a

FIG. 36.

FIG. 37.

handle, and the other end "teased out" by pulling it through a comb made by driving some nails through a board and allowing the points to extend beyond the board.

While in use the board forming the comb may be fastened to a bench or table. In making such swabs, some molders

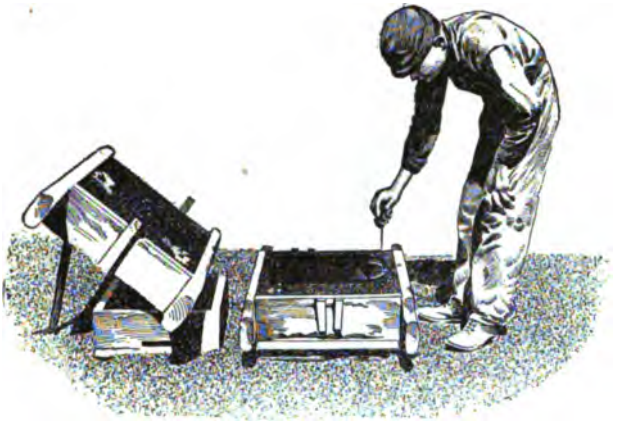

FIG. 38.

use a fine string that will not unravel in water or when dampened. This string is cut into lengths of about 1 foot and a bunch of them tied at one end to form a handle, as described.

FIG. 39.

33. Rapping and Draw-Plates.—After the pattern has been swabbed, it is **rapped** by pounding on the side

of a bar that has been introduced into a hole in the rapping plate, as shown in Fig. 39. It is better, however, to have two holes in the **rapping plate,** one for the **rapping bar** and the other for the **draw-screw.** Some persons make the draw-screw serve for both purposes; this may answer where the patterns are light, but for large patterns there should be a rapping hole as well as a draw-screw hole. If the screw hole is made to serve for the rapping hole also, the thread in the screw plate is soon destroyed, even if the rapping is done on the screw **drawing-iron.** Too much care cannot be taken to have good arrangements for rapping and drawing patterns, for this not only prevents the wear of the pattern, but also saves labor in molding. After the pattern has been loosened by rapping, it is drawn by introducing the **draw-nail** or **draw-iron,** as shown in Fig. 40. While drawing the pattern it should be rapped gently, as shown in the figure. The rapping plate on the pattern shown in Fig. 40 is made large enough to

FIG. 40.

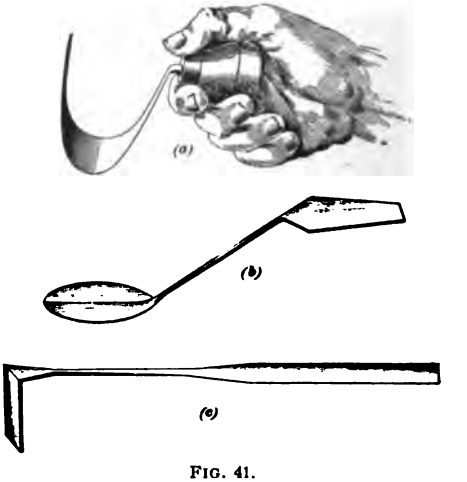

FIG. 41.

contain two holes, one for the draw-iron and one for the rapping bar.

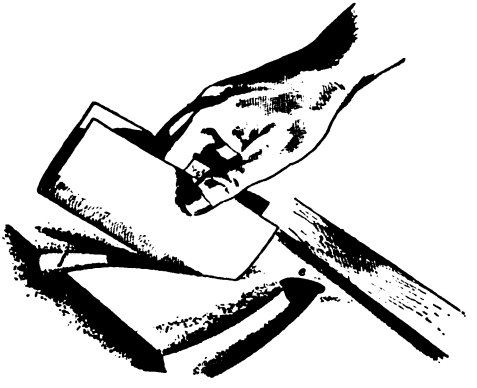

FIG. 42.

34. Cutting the Gates and Riser. — The pattern having been rapped and drawn, the mold is then finished with the trowel and the **double ender,** the latter tool being shown at (*b*) in Fig. 41. The gates for connecting the sprue and riser with the mold are cut by means of a **gate cutter.** The form of gate cutter illustrated at Fig. 41 (*a*) consists of a thin blade of brass or steel bent to the required form and provided with a handle. Another form of gate cutter is shown in use in Fig. 42. This form of cutter consists of a thin sheet of tin or brass bent to the required form and is used as shown in the illustration. After the gates *f* are cut to the bottom of the sprue or riser *e*, Fig. 42, they should be smoothed firmly with the fingers, so as to press down all the loose sand. If this is not done, the iron, when running through them, will carry dirt into the casting. Before smoothing down

FIG. 43.

the pouring gates, it is well, with some molding sands, to wet the top edge of the gates by carefully using a swab or sponge as shown in Fig. 38. In using water in this way around gates, extra care must be exercised not to make any portion of the sand too wet; for this might cause the iron to blow as it passed into the mold, and result in spoiling the casting.

35. Closing and Pouring the Mold. — The mold having been finished, it is **closed** and the flask clamped ready for being **poured,** as shown in Fig. 43. In twenty minutes after the casting is poured, the cope and nowel may be removed. After a few hours, or on the following

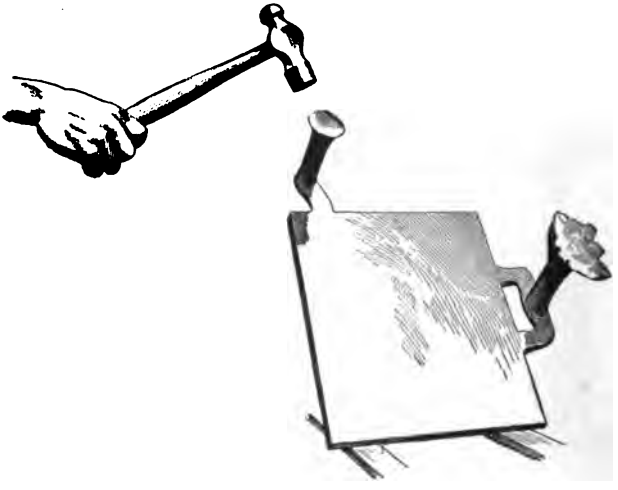

FIG. 44.

day, the casting may be taken from the sand, when it will appear as in Fig. 44, which shows how the pouring gate and riser are connected with the casting. After the casting is cool, the gate and riser are knocked off by using a hammer, as shown in the upper left-hand portion of the illustration, and the casting is then cleaned up, thus finishing the job.

MOLDING BY "BEDDING IN."

LEVELING.

36. Having described the casting of flat surfaces in green sand by "rolling over," we shall now deal with the making of a casting by "bedding in." A bed for a flat plate may be made at the top of the molding floor or at any desired depth below it. In any case, it will be necessary to

FIG. 45.

have some guide to form the bed; this guide generally consists of **straightedges,** arranged as shown at *a*, *b*, and *c*, Fig. 45.

In **leveling up** the straightedges, the first one *a* has a mound of sand placed under each end, so as to keep its under edges free from the floor, and the straightedge is made as nearly level as the eye can judge. A spirit level is then placed on the straightedge and the high end driven down with a wooden mallet or a hammer, the pounding being done on a block of wood (to prevent the hammer marring the face of the straightedge) as in Fig. 46. The next step is to set the straightedge *b* in place on two mounds of sand, as was done with *a*, setting it by eye as nearly true with *a* as possible. Next, the straightedge *c* is placed on

the ends of *a* and *b*, Fig. 45, and the spirit level used to bring the ends of *b* on a level with *a*. This can be done by first bringing one end of *b* to the level of *a* by using the

FIG. 46.

straightedge *c* as shown, and then carrying *c* to the other end and repeating the operation. Still another plan to get *b* true with *a* is to use *c* as shown, and then remove the spirit level from *c* to *b* and raise or lower the end of *b* as may be found necessary.

It must be remembered that both edges of the straightedge *c* must be parallel; this is not necessary, however, in the case of *a* and *b*, the upper edges only of these two being required to be true. These straightedges should have a hole in one end so that they can be hung up when not in use, and not left lying around on the floor, where they are liable to have their edges injured or to be bent or warped from irregular exposure to dampness and uneven supports.

MAKING THE BED.

37. General Remarks. — The straightedges having been leveled as described, the work is proceeded with according as the thickness of the casting to be made requires the bed to be hard or soft. In pouring castings in **open sand,** that is, pouring flat plates without a cope covering, a **soft bed** is generally used. The bed, when down or under

vents are not used, must be soft in order to permit the gases to escape freely from the sand, for there is no head pressure of metal on the bed to drive out the gases, as there is when a plate casting is poured through a cope. In the latter case, the bed is generally made hard in order to withstand the head pressure of the metal. Much more labor is required in making a hard bed than a soft one.

38. Making a Soft Bed.—In making open-sand plate castings, the bed has to be softer for a casting ½ inch to 1 inch thick than for one whose thickness is from 1½ to 3 inches. The reason of this is that the thicker the casting, the greater is the pressure exerted by the metal on the bed, tending to drive the gases downwards into the lower part of it, or to cause them to escape outwards at its sides. The same degree of softness necessary for the thin plate may sometimes be used for a thick one; but the harder the bed can safely be made, the better, as this prevents the weight of the pattern, or of any other light body, making impressions on it and causing an uneven face on the casting. Although, however, it is well to have a bed as hard as practicable, still the danger of going too far in that direction makes it desirable to have the bed too soft rather than too hard. By using care in smoothing soft beds with the trowel and in laying on the patterns, a casting can be produced with almost perfectly true surfaces. In starting to make a bed after the straightedges have been leveled up, sand is **tucked** solidly under *a* and *b*, Fig. 45, so as to prevent the pounding action of the straightedge *c* from disturbing their level. After this is done, sand is shoveled on both the inside and outside of *a* and *b* until it is level with their top. The sand on the outside is then packed down with a butt rammer or with the feet, to prevent the pressure of sand on the inside of *a* and *b* from pressing them outwards.

Next, the straightedge *c* is used to **strike off** the sand level with the top of *a* and *b*. Sand that has been passed through a ¼-inch riddle is now spread over the face of the bed to a depth of about ¾ inch, and then a flat piece of wood

or iron about 8 inches long is placed on each of the straightedges. These pieces *d* and *e*, Fig. 47, should be from ¼ inch to ½ inch thick, according to the desired hardness of the bed—the thicker the piece, the harder will be the bed produced. On top of *d* and *e* is laid the straightedge *c*; a man

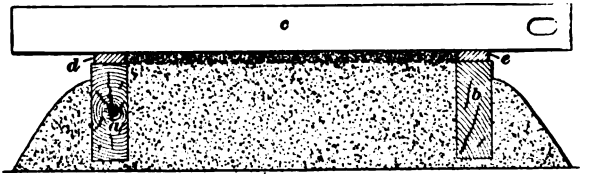

FIG. 47.

is then stationed at each end, holding the pieces *d* and *e* and also one end of *c*. These men then pull the straightedge *c* and the pieces *d* and *e* along, sweeping to the end of the bed all sand that lies above the level of *d* and *e*. This leaves a body of sand—the thickness of the pieces *d* and *e*—projecting above the level of the straightedges *a* and *b*, which sand is next pounded down to the level of *a* and *b* by means of the edge of *c*. To do this, a man holds one end of *c* down on one of the straightedges *a* or *b*, while another man raises the other end from 4 to 6 inches and brings it down

FIG. 48.

upon the raised sand so as to drive it down to the level of the top of *a* or *b* on his side, as shown in Fig. 48. When one

man has gone a distance of about 12 inches, he returns about half way to his starting place and holds *his* end of *c* down on the under straightedge, *a* or *b* as the case may be, while the opposite man raises the other end of *c* and pounds down the sand on his side. This operation is continued by the two men, alternately, until the whole surface of the raised sand is pounded down to a level. When the bed has been thus gone over, its surface will present a series of imprints of the straightedge *c*. To remove these marks the straightedge *c* is dragged in a seesaw manner across the

FIG. 49.

face of the bed, as in Fig. 49, each man being careful to have every stroke a forward one. If this is not done, marks caused by the backward motion of the straightedge would be left on the surface, while the portion that was done properly would be smooth. The portion of the bed shown in Fig. 49 which is nearest the straightedge has been done properly, while the portion near the front of the illustration has been struck off with alternate forward and backward movements of the straightedge so as to leave ridges of sand on the bed.

To accomplish this forward movement requires a little

practice, as it is rather difficult to have every movement a forward one while seesawing the face of the bed. If the face of the bed is struck off by a *straight pull*, not only will the surface be left rough, but the operation is apt to loosen the face of the pounded sand from the underlying soft body, so that when the metal runs in over the sand, it is liable to loosen or lift the sand in such a way as to cause a rough and scabby casting. After the bed has been struck off as described, a fine sieve is used to shake a very thin coating of sand evenly over the face of the bed. A trowel is then used to smooth down the sieved sand, after which the bed is ready

FIG. 50.

and the molder can proceed to build up the sides of the mold with sand, and so give any shape required in the casting. A clear idea of this may be gained from Fig. 50, which shows a man **packing sand** against the side of the pattern *P* in such a manner as to form the sides of the mold.

The sides having been built up as described, a **pouring basin** *g* is made, and then the mold is ready to have the metal poured into it. For pounding down with the straightedge *e*, some molders use a sharp grade of bank or river sand, alone or mixed with common heap sand. This is only necessary where the molding sand proper is of a close, fine grain, as such fine sand is liable to cause scabs on account of its not being sufficiently open to permit the gases created at the face of the bed to escape downwards freely.

Where sharp sand is used to form the face of the bed, it

may be omitted in front of the pouring basin, and this place filled in with a stronger and closer grained sand, as shown at the light spot marked *h*, Fig. 50. For this purpose some molders use ordinary molding sand, or a regular facing sand, which is made by mixing sea coal with molding sand, in front of the pouring basin, in place of the ordinary sand just mentioned. The reason for using a stronger grade of sand in front of the pouring basin is that the metal, when flowing from the basin on to the face of the bed, is liable to break the latter where the sand is weak, so as to cause it to be washed in along with the metal, the result being a rough or scabbed face (on the casting) in front of the pouring basin.

The subject of venting open-sand beds will be treated later on.

39. Thickness of Open-Sand Castings.—The thickness of **open-sand castings** is determined by the thickness of the piece *P* used in building up the sides of the mold, Fig. 50, by the fluidity of the metal when pouring the casting, and by the judgment of the molder in deciding when sufficient metal has flowed into the mold. An iron that is **dull,** or not very fluid, will readily pile up in an open-sand mold, so as to be from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch thicker at the center than at the sides of the mold, for which reason it is difficult to obtain open-sand castings within $\frac{1}{8}$ inch of any specified thickness. To attain even this accuracy, the metal used should be very fluid.

40. Venting Soft Beds.—When soft beds are made as here described, and the castings (where more than one is placed on the same bed) are 8 to 12 inches apart, they will seldom require any venting, except when it is necessary to use fine grades of sand. In such cases vents may be made as described later on in connection with Figs. 51, 53, and 58. Where floor space is limited so that open-sand castings must be placed close together, say 2 to 4 inches apart, it may suffice, where open grades of sand are used, to drive a row of vertical $\frac{3}{8}$-inch vents down the center of the partitions of

sand dividing the molds, as shown at *v*, Fig. 51. There should never be any difficulty in carrying off gases from soft beds when it is desired so to do.

41. Making a Hard Bed.—There are few things in founding in which molders differ so much as in their methods of making **hard beds.** It may be said that there are four degrees of hardness in making beds: The first is the soft

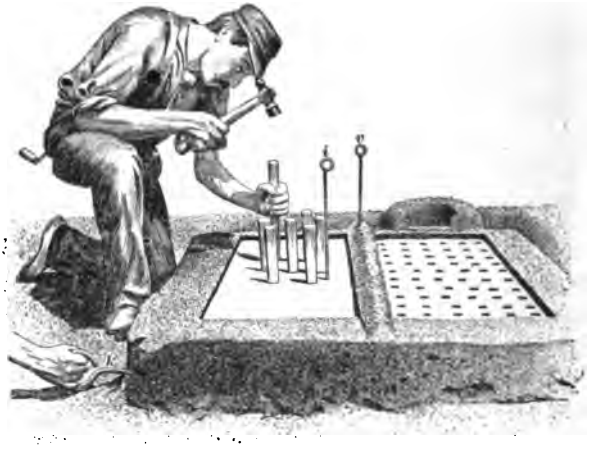

FIG. 51.

bed for open-sand castings of plates ranging from ½ inch to 3 inches thick. The second bed is of the character required for making the prickered plates used in loam molding. The third is for hard beds used for open-sand castings that must be well vented. The fourth is for beds that are used for light and heavy castings in cases where the bed forms the bottom part of a mold that is covered with a cope. The most difficult beds to make are those used for making loam plates requiring long prickers on them, as shown in Figs. 51 and 52, and also in the matter treating on loam molding.

42. Making Beds for Prickered Plates.—In making beds for plates having **prickers** or prongs on them, the depth of the tempered sand requires to be much greater than for plain plates. As an example, the plain plate to be

cast in the bed shown in Fig. 50 can be successfully made with a depth of tempered sand ranging from 4 to 5 inches without any venting; but if it be necessary to have prickers from 4 to 6 inches long on such a plate, the tempered sand should be fully 7 to 10 inches deep. This is due partly to the necessity for packing the sand firmly with the palm

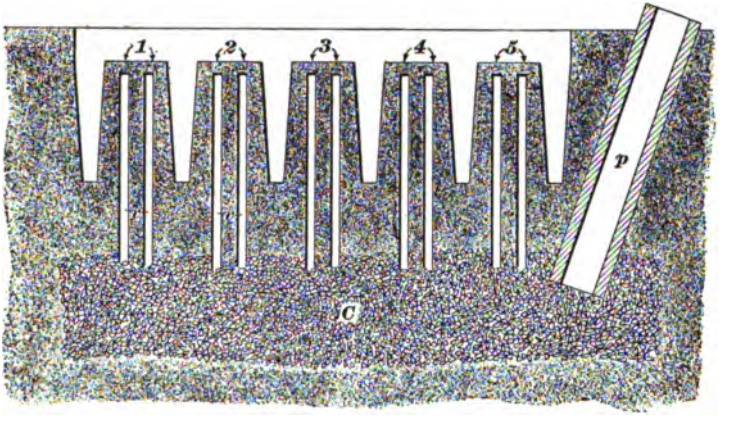

FIG. 52.

of the hand, or the back of a shovel, as every course of sand of from 3 to 4 inches deep is filled in. If sand was shoveled in loosely, as in the case of the soft bed just described, the prickers or prongs, if over 6 inches deep, would be liable to be strained at their bottom ends in such a manner as to burst into each other, or to swell at the end so badly as to raise the face of the mold for the depth of the prickers, and thus cause a solid heavy body of scrap iron instead of the plate casting desired. Some loam plates require prickers or prongs from 12 to 30 inches deep. It is very difficult to make such deep prickered plates in open sand without their blowing more or less when being cast. In some cases it is best to dig deep enough to permit a cinder bed being placed under such plates, as shown at *C* in Fig. 52, and then filling in the tempered sand in layers ranging from 3 to 4 inches deep, and venting each alternate layer of sand with $\frac{1}{8}$- or $\frac{3}{16}$-inch vent wire down to the cinder

bed, which is itself vented through **vent pipe** *p*. Another plan is to have 6 or 10 **pricker patterns** instead of the 1 or 2 used in the case of shallow prickers, and to press them all down one after the other and then before they are withdrawn from the sand take a $\frac{1}{8}$- or $\frac{3}{16}$-inch vent wire, as seen at *i*, Figs. 51 and 53, and carefully vent down from the face of the mold to the cinder bed between all the pricker patterns, making the vents about 2 inches apart, as at *v*, *v*, Fig. 52. These vents, coming to the surface of the mold, must be stopped up with the end of the finger and then all the finger holes filled with sand and the surface sleeked over to make the face of the mold smooth, as at *1*, *2*, *3*, *4*, *5*.

In some cases, instead of carrying the gases from these vertical vents through the cinder bed, the venting can be

FIG. 53.

done by using a long $\frac{1}{4}$-inch or $\frac{3}{8}$-inch vent rod driven in at the bottom of the tempered sand to bring the gases to the side of the bed, as seen by the vent wire *k*, Figs. 51 and 53, and the row of vents *k* in Fig. 58. In packing the sand by layers or courses in these beds, care must be taken not to make them so hard that the molder cannot push the pricker pattern down by hand to a depth of 6 to 8 inches. Beyond this depth it may often be necessary to use a hammer to drive the prickers, as in Fig. 51. Another point to be noted

in making deep prickered plates is never to use any sand but that which has been well tempered and passed through a ¼-inch or ½-inch riddle.

Care must be taken to work the sand as dry as it can be used and give good results; it must not be so dry, however, that there will be any risk of the sand running back into the holes left by the pricker pattern after it has been withdrawn. The pattern used for making prickers or prongs on plate castings should always have a handle from 6 to 8 inches long and of convenient form for the hand. A good form of pricker pattern is illustrated in Fig. 54, where it is shown held in the position generally used when pressing it into the sand.

FIG. 54.

Deep prickered plates usually give trouble at the first attempts, but with some experience in molding them, and by following the directions here given, they should be made successfully.

43. Hard Beds for Open-Sand Castings.—Castings with **lugs** or long **projections** on them may be cast in open-sand molds if it is not of much importance whether the cope, or upper side, of the casting is a little rough. In making such castings, the straightedges are leveled as already explained. Then, tempered sand is filled in and rammed down evenly and firmly to nearly the top of the straightedge, using the butt of the rammer or the feet. When this is done, a straightedge having its lower edge cut down ½ inch at each end *c*, Fig. 53, is used to strike off the bed so that its surface will be ½ inch below the top of the straightedges *a* and *b*. Then the surface of the bed is vented all over with a ⅛-inch or $\frac{3}{16}$-inch vent wire, the vents being made about 1 inch apart. These vents may be carried down to a cinder bed or led

from under the bed with $\frac{1}{4}$-inch or $\frac{3}{8}$-inch vents leading from under the straightedge, as seen by the vent-wire projection at *k*. After the surface of the bed has been well vented, the palm of the hand is passed over the surface of the bed to close up the top of the vent holes. Riddled sand is then shoveled on to about $\frac{1}{8}$ inch higher than the top of the straightedges *a* and *b*. Pieces *d* and *e*, about $\frac{1}{4}$ inch thick, are now used in conjunction with the straightedge *c*, to strike off the bed as shown in Fig. 47. This done, the surface of the bed is pounded down with the straightedge *c*, and the face of the bed struck off in a seesaw manner, and finished as described in Art. **38.**

MOLDING PLATES WITH PROJECTIONS IN OPEN SAND.

44. General Directions.—The hard bed, Fig. 53, having been completed, it may be used for casting plates having projections, flanges, lugs, etc., of which the pattern shown in Fig. 55 is a type. In bedding such a pattern on a level bed, it is first set on the bed and pressed down so as to leave an imprint of its projections; it is then removed and the shovel used to cut away the greater part of the sand where the lugs come, after which the trowel is used to cut away the sand to within about $\frac{1}{4}$ inch of the inside of the imprint. This leaves the bed as seen in Fig. 56. The pattern is next set back and hammered down solidly on the bed, the molder striking on a

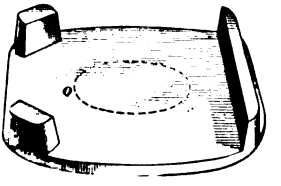

FIG. 55.

FIG. 56.

block as in Fig. 57; after this, sand is rammed up against the outside of the lugs and the edges of the pattern and the

FIG. 57.

mold vented, as shown at *k* in Fig. 58. Next the pattern is **drawn** and the mold finished ready for the metal, as shown. It is of *especial importance* that a block of wood or

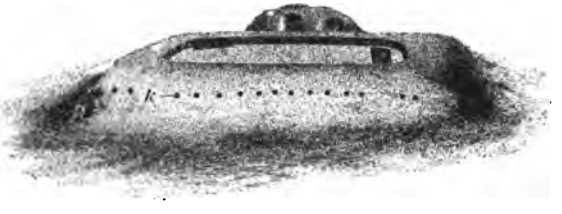

FIG. 58.

a heavy plank be used to pound on when bedding in patterns; no sledge or heavy hammer should be used on the bare face of a pattern.

Another method of making a casting from a pattern like that shown in Fig. 55, by bedding in, is to have a hole cut in the pattern about the size shown by the dotted line at *o*, and then to set its projecting lugs on mounds of sand and **tuck up** the pattern on the inside through the hole *o*, as shown in

Fig. 59. This answers well where the patterns are not of large area, but for large plate surfaces with patterns having flanges or lugs, the plan shown in Figs. 56 and 57 is a good

FIG. 59.

one. One objection to this plan, however, is that the projections, flanges, or lugs are faced with common heap sand. In order to obtain a smooth surface throughout, such projections as shown in Fig. 55 should be faced on the inside with sand mixed with sea coal.

45. Facing Inside of Projections.—To face the inside of projections, flanges, etc., when the pattern has been bedded in the manner shown in Figs. 56 and 57, the pattern must be drawn before the outside of the projections are rammed up, and then a section of the inner face of the projection cut out, as seen at *a*, Fig. 60. A piece of board or plank must next be laid against the projection, as seen at *b*, and then the cavity at *a* rammed up with facing sand that has been mixed with sea coal. A $\frac{1}{8}$-inch vent wire is used to vent the face and sides of the projection, keeping the vents about 1 inch back from the face of the board *b*, and driving them to the cinder bed or horizontal vents, as seen

at *k*, Figs. 51, 53, and 58. This done, the tops of the vent holes are stopped up with the finger and then filled with sand and the face of the mold finished with a trowel, after which the board *b* is removed. If the section *a* is not long enough to cover the entire inner face of the projection, another section joining the portion just faced is cut out and the board *b* again replaced and the operation repeated as described. This operation is repeated until the whole face of the projection has been lined with rammed facing sand from 1 inch to 1½ inches thick. The length of *a* will depend on the

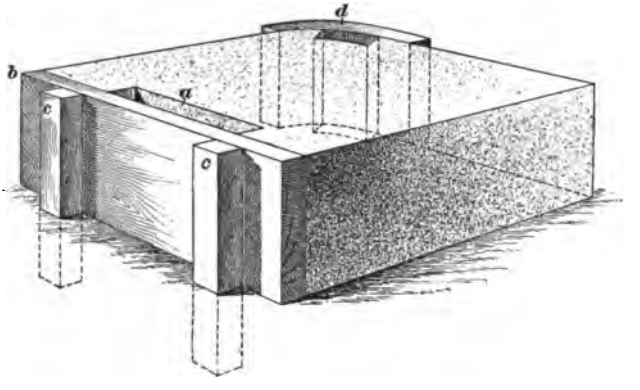

FIG. 60.

length of the surface to be covered with facing sand; this can extend from 4 inches to 4 feet, so long as the board *b* is kept in the required position. To hold such boards, or **formers**, as *b* in the right position while the cavity at *a* is being rammed, stakes *c* are driven into the floor. The space or cavity at *a* is rammed with ½-inch to ¾-inch rods, or with a small hand hammer having a peen 1½ inches wide and ½ inch thick. Care must be taken to face and ram the space at *a* evenly and firmly. In the case of projections having forms that differ from the straight surface at *b*, it will be necessary to use special pieces or patterns as shown at *d*, the whole being rammed, vented, and finished the same as the straight piece *a*. Boards used for the formers *b* must be smooth on the side forming the face of the projection.

MAKING HARD BEDS FOR COPED CASTINGS.

46. Large surfaces covered with a cope permit of harder beds being used without causing the metal to blow and create scabs than can be used for open-sand work. In making these beds, it must be remembered that the sand should be as dry as can be easily worked, and should be vented as well as possible. The operations, so far as leveling the straightedges is concerned, are nearly the same as those described in Art. **36,** the only difference being that the straightedges *a* and *b* will be set down into the floor about two-thirds of their depth, instead of being set up above the floor, as seen in Figs. 45 and 46. After the straightedges are leveled, sand that has been well tempered and riddled is filled in between them and struck off level with their top edges; the sand is then rammed down with the feet as far as possible, and then the whole surface of the bed is rammed with the butt of the rammer. This will bring the rammed sand down to about 2 inches below the top of the straightedges, when these are about 6 inches deep—which is about as deep as such a course should be. The sand having been butted solidly, common sand is again shoveled in and struck off to the level of the top of the straightedges. This is then butted down lightly all over the bed and a straightedge *c*, Fig. 53, whose ends are cut down $\frac{1}{2}$ to $\frac{3}{4}$ inch, is used to **strike off** the bed, which is then closely vented all over the surface with a $\frac{1}{8}$- or $\frac{3}{16}$-inch vent wire, and the top of the vents stopped up with the palm of the hand; next, sieved sand, which for some classes of work may be mixed with sea coal, is shoveled in and struck off with the use of $\frac{3}{8}$-inch strips on the straightedge *a* and *b*, Fig. 47, as described in Art. **38,** and then pounded down and finished, as already described.

VENTING HARD BEDS.

47. Objectionable Method.—Some molders make a practice of venting direct from the face of the bed and then poking each hole with the finger to stop the surface of the

vents, instead of having the tops of the vents about ¼ inch below the surface of the bed. After the upper ends of the vents are all stopped with the end of the finger, facing sand is packed solidly into each hole with the fingers and the bed is then smoothed with a **surface block** (preferably of hard wood), measuring about 3 inches by 8 inches, with the corners a little rounded. This plan will succeed if carefully carried out, but should the top of a few holes be carelessly stopped up, there is danger of the iron bursting through the vents and running down the vents to the cinder bed, if there is one. Then, again, gas might become confined in the cinder bed and, by exploding, create an upward pressure in the vent holes and lift the sand from the top of those vent holes that have not been filled firmly with sand. A little study of this method of venting will make its objectionable features evident.

48. Surface Venting.—Where beds are desired with very hard surfaces, or where the sand is of such a nature as to scab readily, it is a good plan to bring the vents as close to the surface as practicable. The following is a plan for surface venting that, if followed, will dispense with the finger-poking of the vent holes and will insure hard beds being reliably vented. The plan consists in ramming up solidly and striking off the common sand within about ¼ inch of the top of the straightedges, Fig. 53, and then covering the surface of the bed with facing sand mixed with sea coal, so that it projects about 1¼ inches above the top of the straightedges, using pieces 1¼ inches thick under the straightedge *c*, as shown at *d* and *e*, Fig. 47. After this is done, a butt rammer is used over the entire surface, in the manner shown in Fig. 61. In butting the surface of such a bed, the operator must make sure that no part of the surface is missed, and the butt rammer must be applied lightly so as not to make the face of the bed too hard. To insure a smooth surface to the bed, no sand should be allowed to stick to the face of the butt when ramming; a brass butt is good for such work. The sand, after being butted, should

project above the straightedges about $\frac{1}{2}$ inch. The bed having been butted all over, its surface is then vented with a $\frac{1}{8}$-inch wire, placing the holes about 1 inch apart, and driving the vent wire down to the cinder bed—should there be one under it. If there is no such bed, then $\frac{1}{4}$-inch or $\frac{3}{8}$-inch vent rods, set horizontally, as seen at *k*, Figs. 51, 53,

FIG. 61

and 58, will have to be used. After the venting, the bed is "struck off" in a seesaw manner, as already described, and facing sand sieved all over its face as thinly as possible. This done, the hardwood finishing block (see Art. 47) is worked all over the face of the bed to make it smooth and ready for finishing with the trowel. The application of the smoothing block not only gives a finish to the surface of the bed, but it also assists in firmly stopping up the top of the $\frac{1}{8}$-inch vent holes; this will not only prevent any iron from bursting into them, but will also prevent any confined gas from forcing its way through the holes into the mold, which would break the face of the mold, causing scabbing or lumps on the face of the casting. In some cases where

there is extra danger of scabs being produced, the reliability of the bed may be increased by first venting it with a ¼-inch vent wire, as seen at Fig. 53, before the 1¼-inch depth of facing sand is shoveled on. When this latter plan is used, the vents from the face, made with a ⅛-inch vent wire, need not extend to the cinder bed.

BEDDING IN.

49. Objectionable Method.—The methods that have so far been described are the proper ones for forming the bottoms of molds that are bedded in; there are other methods in use, however, that are neither mechanical nor

FIG. 62.

proper. Thus: A workman having to mold the pattern shown in Fig. 55, makes a hole in the floor and fills it with sand, without doing any packing; or else he builds a mound of soft sand. On this he lays the pattern and jumps upon it; after which he digs out the sand from the lugs, again jumps upon the pattern, gets off, and digs out more sand from under the lugs, and so on until the whole of the under

surface of the pattern is in contact with the sand, if the pattern does not break in the meantime. Then he lays a wooden block on the pattern, and pounds it with a heavy sledge hammer, as shown in Fig. 62, until the face of the pattern is bedded into the sand to a depth of ½ to 1 inch, depending on the molder's weight and strength and the weight of the sledge. This operation is repeated until the mold is made or something breaks. This, then, is an illustration of how a thing should *not* be done.

Some patterns may be bedded in by merely forcing them into soft sand; but care and good judgment are required in doing such work. When a molder uses this method indiscriminately for all bedded work, the practice is certainly reprehensible.

50. Ground Beneath Prepared Beds and Molds. Having dealt with the preparation of soft or hard beds to form the bottom of molds, attention is now called to the necessity of knowing, as far as possible, the condition of the **earth** or **ground** below the bed. Many castings have been lost because the ground underneath the beds of the molds is in a soft condition; we may make the prepared bottom of the molds as hard as possible and still have castings badly swollen or distorted or lose all the metal out of the mold if the **under ground** is not solid. If there is any doubt as to the solidity of the under ground, the only reliable procedure is to dig down and test the under ground with pick and shovel, or a fair idea of the condition of the ground may be obtained by driving down pointed iron bars. Where heavy or deep castings are to be made over untested ground, it may often be necessary to dig down from 2 to 4 feet below the level of the bottom of the molds, in order to be assured that the earth is sufficiently solid to withstand the pressure of metal that will be put upon the mold when it is poured. A source of trouble in many foundries arises from the careless manner in which holes left by old molds have been filled up with sand. Some molders, after taking out a deep casting that has been made in the floor, will merely throw in some water

and loose sand until the hole is filled to the level of the floor, and then in a few days, dig out the same hole to make a shallow casting, without going down to solid ground; many castings have been badly **strained** or **lost** on this account. When deep castings (or shallow ones, even) are taken out of the floor, all the dry and loose sand should be shoveled out and then dampened and tempered before being shoveled back into the hole. This sand should be shoveled in in courses of from 5 to 8 inches deep, and butt-rammed until solid. If this practice is followed, any molder who may desire subsequently to make other castings over or near the same place, can rest assured that the ground under or at the sides of his mold will be solid, and if his mold also is firmly made, he can produce a casting free from swells or strains on its lower side.

CAVITIES IN BOTTOM OF CASTINGS.

51. There are many molds having bodies of sand extending upwards from the bottom that are not covered

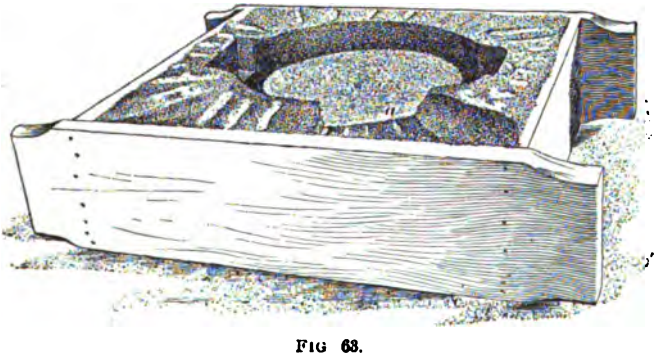

FIG 63.

with iron until the metal has nearly reached the top of the mold; flat-bottomed annealing pots afford an example of this. Figs. 63 and 64 illustrate this form of mold, Fig. 63 being partially broken away at *a* to show the projection in the mold.

The gases generated at the bottom of such molds when

the pouring is commenced endeavor to rise upwards through the vents formed in the projection; this, together with the fact that the pressure of the metal over the top of the projection at *a*, Fig. 64, is less than at the bottom *b*, is liable to

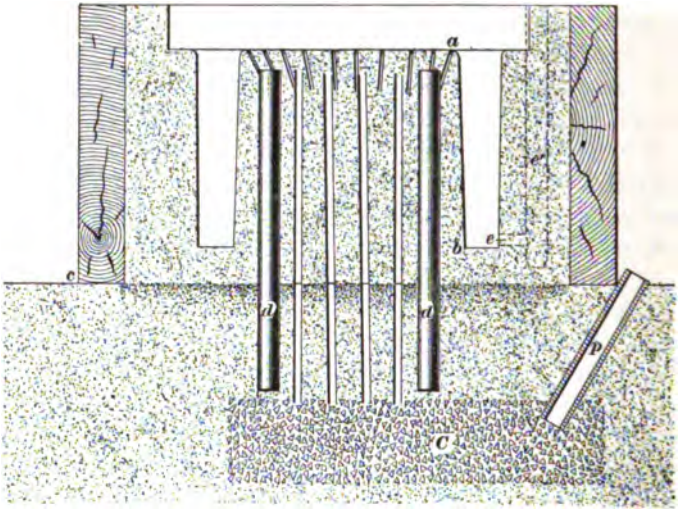

FIG. 64.

give trouble. Then again, when the metal commences to cover the flat surface of such projections as *a*, its movement is much slower than the rise of the metal at the bottom of the mold; the result of this is that if there should be any blowing or bubbling of the iron as it comes to the top of the projection *a*, the rise of the metal will be so slow in creating pressure over the face of the projection that scabbing will take place, endangering the safety of the casting because of the liability of the iron getting into the vent holes leading down from the face at *a* to the cinder bed or other outlet for the vents. To prevent the projection from **blowing** the casting, the surface at *a* is made as soft as practicable and the large vents not brought nearer than within $\frac{3}{4}$ inch of the top surface of the projection. This is done by ramming up the sand firmly to within $\frac{1}{2}$ inch of the top and then striking it off with a straightedge cut away

at the ends, as in Fig. 53. The bed having been struck off ¾ inch below the top of the surface, a ¼-inch **vent rod** is used to vent closely all over the area down to a cinder bed *C* or other outlet for the gases. The tops of these vents are then stopped up with the end of the finger, a very open grade of facing sand shoveled in over them and pressed down with the fingers and palm of the hand as softly and evenly as can be done. This lightly packed sand should extend about ⅛ inch above the level of the face at *a*, so that the top of the sand may be struck off to give a smooth and finished face to the projection. Before striking off this extra ⅛-inch thickness of sand, the face is closely vented with a fine wire, about $\frac{1}{16}$ inch in diameter, to a depth of about 3 inches, thus connecting the face vents with the large ¼-inch vents, as in Fig. 64. The ⅛-inch thickness of sand is struck off and the surface finished with a **trowel,** leaving the top of the projection as it appears at *a*. The mold is shown made above the level of the floor, but it can be made in a hole dug in the floor, so as not to require any part of the flask but the cope; in fact it would be better to make such castings in the floor, if the shop arrangement permits digging, as then there cannot be any danger of a run out at the bottom of the nowel at *c*. This casting may be poured by an **inlet gate** *e* connecting with the **upright gate** or **sprue** *e'*. The cope is not shown; it is a wooden one, 6 inches deep, with bars about 5 inches apart. In pouring this mold, the cope is held down with about 800 pounds of iron. The riser should be kept closed during pouring so as to maintain a pressure of gases in the mold, as this will assist the gases in finding their way down to the cinder bed.

RODDING PROJECTIONS.

52. There are a great many projections like that seen in Figs. 63 and 64 that must be **rodded** in order to make sure that the buoyancy of the metal will not lift them. To make sure of this in the casting shown, six ⅛-inch round

rods, as at *d*, are **clay-washed** or covered with flour paste to make the sand stick to them, and then driven equally around the circle to the depth seen in Fig. 64. In the hands of a good molder this projection will stand without rodding, but it is always advisable to take as few chances as possible. The question as to whether it is wise or not to rod a projection in this manner is often one of judgment, as the condition of the patterns, flasks, and sand has often much to do with determining what plan it is best to follow. All material that is lighter than liquid metal will rise to the top of it and float, just as cork will float on water. Sand is a lighter substance than iron, and for this reason, if the rammed sand is not held down by some means, it will rise and let the iron underneath it. The **specific gravity*** of cast iron ranges from 6.9 to 7.4; brass, from 7.8 to 8.4; whereas rammed molding sand ranges from 1.40 to 1.80. Taking bulk for bulk, a cubic foot of iron weighs about 450 pounds, whereas a cubic foot of rammed sand weighs about 100 pounds, the specific gravity of iron thus being about 4½ times that of rammed molding sand. This means that a projection of rammed sand, such as that seen in Figs. 63 and 64, would have to be about 4½ times heavier than it is before it would remain in position as molded were it not assisted by other forces. One aid to this is the coherence of the tempered and rammed sand. This prevents it from being readily separated. We find this principle illustrated in the necessity for using parting sand on sleeked joints, in order to separate the sections of molds, as previously described. This coherence in the sand of the projection would leave but little risk if the rods at *d* were omitted in this special casting, providing it was well rammed at the bottom. This is where the danger lies with all such work; any softness at the lower edge of such projections as

*The specific gravity of any substance is the ratio of its weight in air compared with an equal volume of pure water at 62° F. For example, 1 cubic foot of cast iron weighs about 450 pounds and 1 cubic foot of water about 62.355 pounds at 62° F. The specific gravity of cast iron is, therefore, about $\frac{450}{62.355} = 7.2$.

this allows the metal to undermine the projection, and if the metal once gets underneath it, it will rise unless held down by rods or some other means. Then again, it is necessary to guard against these projections being loosened at the bottom when jarring the pattern to draw it from the mold. Still further, patterns are often deficient in taper, so that in trying to draw them, the whole projection may be started or lifted from the bottom and so leave an opening for the metal to pass under. If any doubt exists as to the safety of a projection, it is better to use the rods *d*, and so prevent possible loss of the casting. Evidently no positive rule can be given for such work, but a study of the principles here outlined, together with his knowledge of the work, will enable the molder to arrive at a right decision in any given case.

TAPER ON PATTERNS.

53. In the last article, reference was made to the danger of **starting** projections, etc., at the base by reason of a lack of taper in the patterns. As a rule, a pattern should be given all the taper that can be practically allowed. The greater the taper, the less labor will be required in finishing the mold, and, also, the longer the pattern will last. The deeper a pattern is buried in the mold, the more taper it should have. In such cases as Fig. 21, where the bottom of a deep casting is required to be nearly the same thickness as the top, the pattern must not have more than a certain taper, as explained in Art. **28.** Where the conditions are not exacting, however, it would be much better to double the allowance of $\frac{1}{16}$ inch to the foot there given. This would give us $\frac{1}{8}$ inch per foot of taper for whatever depth the patterns might be rammed in the sand. In designing work calling for such projections as are shown in

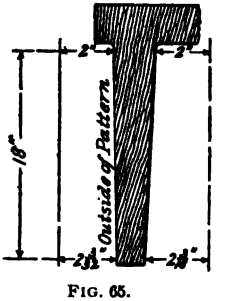

FIG. 65.

Figs. 63 and 64, every effort should be made not to have less than $\frac{1}{8}$ inch per foot of taper on the inside projections. Such a pattern as the one in question would, therefore, have its top and bottom dimensions as shown in Fig. 65, if the length of projection were 18 inches as shown. It will here be noticed that $\frac{1}{16}$ inch per foot is allowed for the outside taper and $\frac{1}{8}$-inch taper for the inside, where it is most needed. Not only should patterns have good taper but they should also be well provided with arrangements for drawing the pattern. In deep patterns, this calls for draw-irons, which are screwed to the side of patterns, as shown in Fig. 21.

DEVICE FOR DRAWING DEEP PATTERNS.

54. Where deep patterns are used to give **parallel** castings, or where difficulty is apprehended in getting a

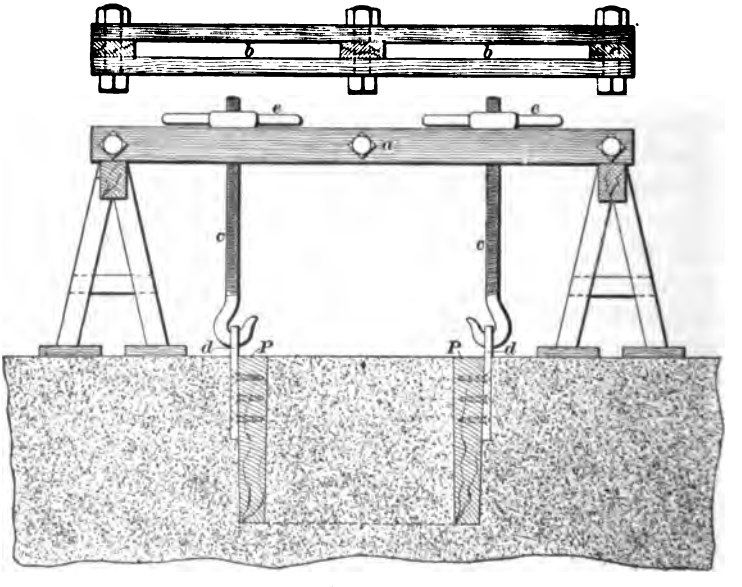

FIG. 66.

pattern out of the sand, draw-screws are provided and used after the manner seen in Fig. 66. Here a built-up wooden

beam *a* having openings at *b* is placed across the mold on **blocks** or **wooden horses**; the draw-screws *c* are hooked into the draw-screw holes *d*, a man is placed at each screw, and then at the word "round" each man turns the screw or nut *e* one revolution only. The word "round" is again called out and another revolution made. This is continued until the pattern *P* is out of the sand. The giving of directions for every turn of the screws is to insure that all parts of the pattern will be raised the same amount, which aids greatly in drawing the pattern successfully. If one side comes out faster than another, it not only causes the pattern to bind in the sand, but in the case of molds having projections, Figs. 63 and 64, there is great liability of starting the projections from their bases, even though they be well rodded; for in such cases the act of starting the base might permit the iron to pass in at the line of separation and so into the vents, even though it did not lift the whole projection. To have the iron run into the vents at the base of the mold is as bad as lifting the whole projection, for in either case the casting will be lost.

FOUNDRY WORK.

(PART 2.)

GREEN-SAND MOLDING.

JOINTS OF PATTERN.

JOINTS FOR PARTING CIRCULAR FORMS.

1. The simplest form of **joint** and the one most used is the straight joint, the manner of making which was

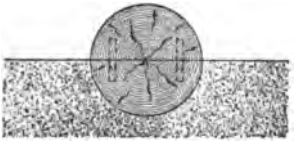

FIG. 1.

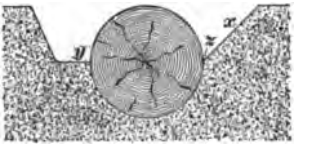

FIG. 2.

described in *Foundry Work*, Part 1. Joints for parting circular forms or deep recesses are shown in Figs. 1 and 2. The method shown in Fig. 1 is used when the pattern is made in two parts, and permits of half the pattern remaining in the nowel, and the other half coming up with the cope when dividing the two parts of the flask. While this method can be followed in many cases, there are others where the pattern must be made in one piece and the joint made according to one of the two methods shown in Fig. 2. The joint shown on the right at x is bad practice, as some sand will often be left sticking in the sharp angular pocket

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formed against the pattern at *z*. When sand does stick in such pockets, it is difficult to patch them without causing a heavy "fin" on the casting, or taking chances of a "crush" at the joint. Then again, such a form gives a very poor bearing for gaggers, the setting of which is explained farther on.

By making a joint as at *y*, on the left of Fig. 2, every opportunity is afforded for a good bearing for gaggers, and for obtaining a "clean lift." Should any of the joints break and require patching, this can be done without much danger of leaving large fins on the casting or causing the mold to crush, owing to the flat surface at the joint, which gives a good guide for patching any broken edges. It is chiefly in heavy castings that cutting down in this manner is practiced. Small patterns are usually divided as in Fig. 1 or provided with follower boards.

JOINTS FOR IRREGULAR FORMS.

2. Fig. 3 illustrates a method of making joints by having the parting line of the cope and nowel conform to the

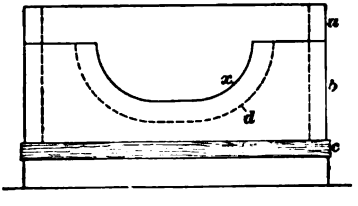


FIG. 3.

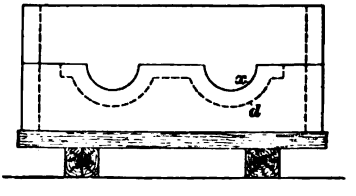


FIG. 4.

shape of the joint of the pattern. The illustration represents the end view of the cope *a*, nowel *b*, and bottom board *c*, the cope being in place for ramming up. The dotted line at *d* shows the lower line of the pattern, while *x* is the face line of the pattern and the line of separation between the cope and nowel. Another example of this is seen in Fig. 4, which shows the side view of a cope and nowel, the lines of the pattern being at *d* and *x*, as in Fig. 3.

THREE-PART MOLDS.

3. Three-Part Flasks.—Many patterns are of such a form as to require two or more parting lines. Sheave wheels and wheels having flanges are the most common representatives of this class of castings. The most common way of casting such pieces is to have as many parts to the flask as there are parts in the mold. One method of molding and casting a flanged pulley is illustrated in Figs. 5 to 7. The two parts of the pattern, P and P', are placed in the molding board and the cheek or intermediate part f of the flask is placed around them. This part is rammed up and struck off as shown in

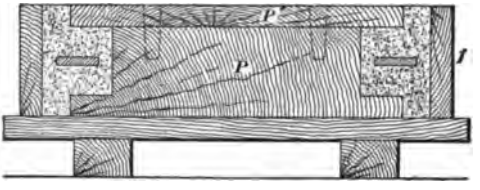


FIG. 5.

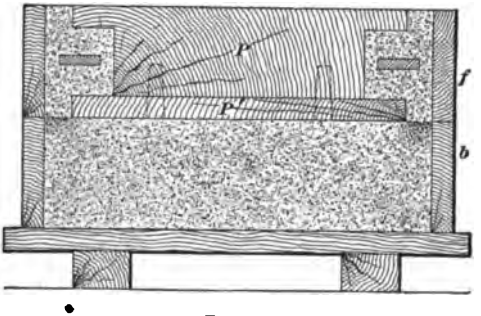


FIG. 6.

Fig. 5. The bottom board is then put on and the part turned over. The molding board is removed, parting sand sprinkled over the joint, the nowel placed on, rammed and struck off. The molding board is then placed on the nowel and both parts turned over together, and the bottom board removed, when they will appear as shown in Fig. 6. Parting sand is then sprinkled over the joint, the cope put on, the sprue pin located, and the cope rammed. The sprue pin is then removed and the pouring basin e formed. The

cope is next removed and the groove vented, as shown in Fig. 7. After venting the intermediate part, the section P of the pattern is drawn, the cheek or intermediate part f lifted

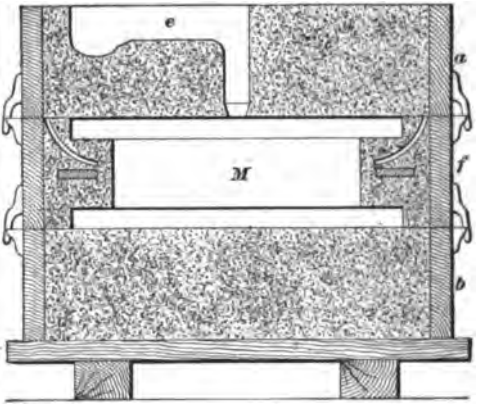


FIG. 7.

off and turned over, after which the pattern section P' is drawn, and the mold cleaned. When the intermediate part and the cope have been returned to their places, the mold will appear as shown in Fig. 7.

4. Making Three-Part Molds in Two-Part Flasks. A three-part mold may be formed in a two-part flask by having an intermediate body of sand between the cope and the

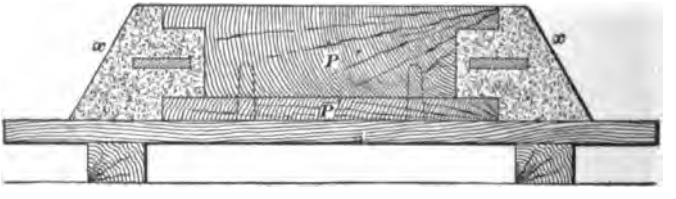


FIG. 8.

nowel. This is illustrated in Figs. 8 to 10, in which the pattern described in Art. **3** is used. The pattern is placed

upon a mold board and weighted down, after which sand is packed around it to form a joint, as at x, Fig. 8. The cope

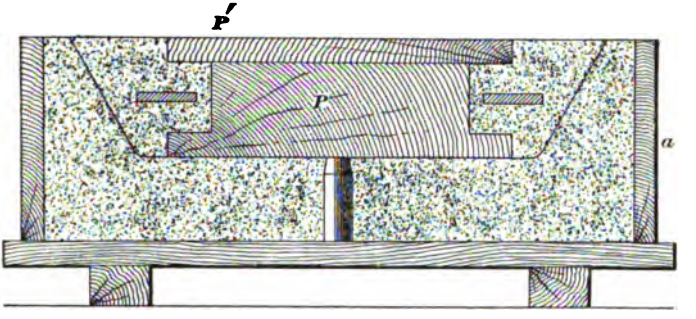


FIG. 9.

is now set on and rammed up, after which the whole is turned over—then appearing as in Fig. 9. Next, the nowel is set on and rammed up, after which it is lifted off and the pattern section P' drawn; the nowel is then set back, and both parts clamped and rolled over. The cope is next lifted

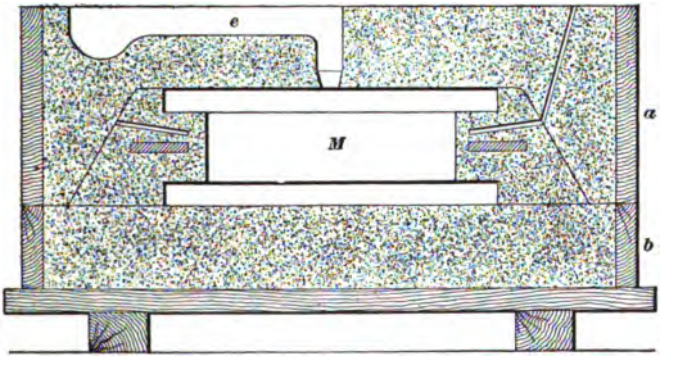


FIG. 10.

off and the pattern section P drawn; the mold is then finished and the cope set back in place, when the whole will appear as shown in Fig. 10. Parting sand must be used on all the joints.

STARTING THE JOINT IN LIFTING.

5. It is important not only that the joint in the mold be properly constructed, but also that means be provided for properly separating the parts, as a good lift often depends on the manner in which the cope is started. It is necessary to **start** some copes evenly all over the joint, while others part better by starting one side before the other. In light work, there are many copes that are best raised by being rolled up, as in Fig. 11. In rolling up a cope, it may be advisable to have it go upward and toward the hinge, as shown by the dotted lines in Figs. 11 and 12; or on the other hand it may go upwards, first describing an arc away from the hinge and then towards it, as shown by the dotted line in Fig. 13. This movement can be given by arranging the hinges as shown in Figs. 12 and 13, from

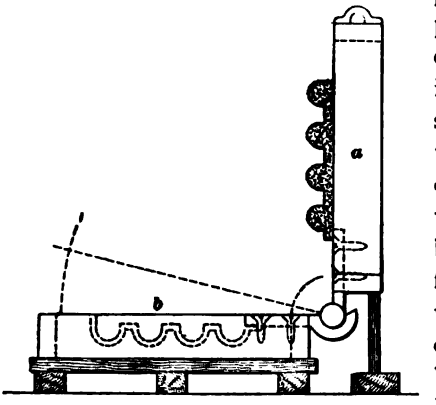


FIG. 11.

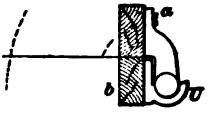


FIG. 12.

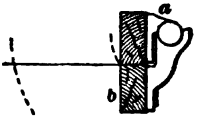


FIG. 13.

which it is clear that the matter of having a cope go upwards from or toward the hinged side can be controlled, thereby assisting in getting good lifts when a movement in either direction will do this. Of course, the farther from the joint the center of the hinge is, the more rapid will be the outward or inward movement.

MOLD BOARDS.

6. Their Use in Forming Joints.—In making the mold for small castings (either of iron or brass) that have irregular joints, much time and labor may be saved by using a **mold board** that will form the joint; then, when the board is lifted off, parting sand can be sprinkled on and the joint is ready for the cope. Many persons making light work have the mold board so perfected that it is often difficult to perceive where the joint is on the casting. There are four classes of mold boards: (1) the *wooden* mold board, which is carved out to give the desired shapes to the joints; (2) the *sand-and-composition* mold board; (3) the *plaster-of-Paris* mold board; and (4) what is called the *match board* or *match plate*. The sand-and-composition mold boards are the ones generally used. Mold boards are sometimes called **odd sides.**

7. Sand Mold Boards.—The usual method of making sand mold boards is to ram up a nowel (harder than usual),

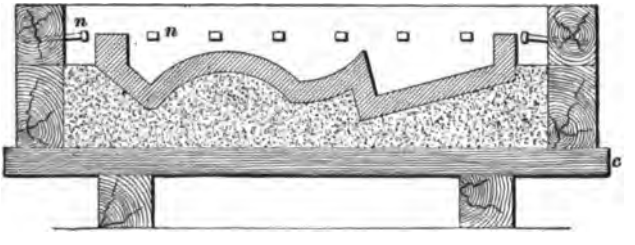


FIG. 14.

and then, after making a good firm joint, set upon it a frame, having nails driven in at its sides, as shown at *n*, Fig. 14; these nails are driven into the frame to hold the sand when using the mold board. When this frame is set on, new molding sand (tempered with very thick clay wash or else made up of 1 part flour to 10 parts sand) is shoveled in and rammed as hard as possible, after which a bottom board like the one shown at *c* is nailed on to the bottom of the frame and the frame and board then lifted off. The

surface of the mold board is now sleeked to repair any broken edges or parts that may have stuck down in lifting it off, and a little molasses water is blown over the surface

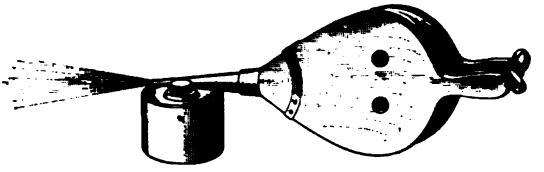


FIG. 15.

to strengthen the joint. The molasses water used in finishing the joint may be blown from the mouth or from a special sprinkler attached to a pair of bellows, as shown in Fig. 15. Another form of sprinkling device for use with a pair of bellows is shown in Fig. 16. This done, the mold board should be set aside for a day or two to harden, after which it is ready for use. In light work, the preservation of the joint edges of sand mold boards sharp and unbroken is of the utmost importance. It will help to preserve them if all the sharp edges are stiffened with nails driven close together, allowing the heads of the nails to come flush with the face of the sand forming the mold board; even then, the edges may become ragged and cause bad joints.

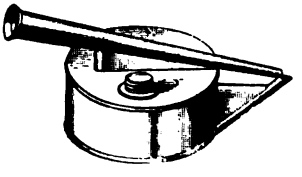


FIG. 16.

8. Composition Mold Boards.—In place of ramming the frame in Fig. 14 with molding sand, a composition may be used that will become harder and last longer than the sand mold board. A composition often used is one made up of fine sand, boiled linseed oil, and litharge; the sand should be very dry. Add 1 part of litharge to about 20 parts of sand, mix them thoroughly and then sift the whole through a fine sieve. Temper this mixture with the oil to the same temper as sand intended for ordinary green-sand molding. The mixture is rammed, as one would ram a mold, to a degree of hardness equal to that generally required in copes. The

ramming done and the bottom board nailed to the frame, the mold board is then lifted off and left to dry for about 12 hours, when it will be ready for use. Before putting the board away, its edges and surface should be finished in the same manner as sand mold boards, using linseed oil instead of the molasses. The oil gives the sand firmness, the litharge being used as a drier for the oil.

It is not essential that molding sand should be used entirely, as almost any sand of fine grain will do. Parting sand mixed with one-half molding sand gives good results. If at any time the corners or edges are found to be broken, they can be mended by patching with beeswax. To form the separation between this mold-board mixture and the molding sand on which it is rammed, a regular parting sand is used. Where the mold board is too large to lift off the nowel, they can both be rolled over and the nowel lifted from the mold board, and the sand then carefully removed from the face of the mold board.

9. Plaster-of-Paris Mold Boards.—Plaster-of-Paris mold boards are often used where, from the crookedness of

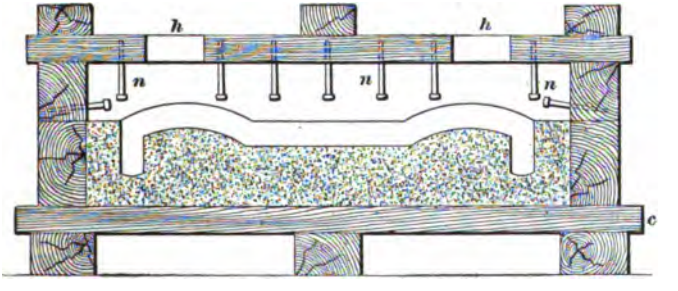


FIG. 17.

the pattern, other classes of mold boards cannot be made as cheaply or as perfectly fitted or kept as true during use. This material gives a very hard mold board on which to ram, but great care must be taken not to break any of its edges, as, even with care, the working in and out of the pattern is very liable in a short time to cause the edges to be ragged

and broken; and no durable method of patching such broken edges has yet been devised. Fig. 17 shows the mold board in process of construction, while Fig. 18 shows it ready for

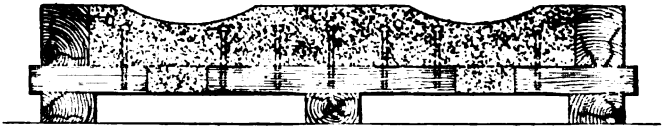


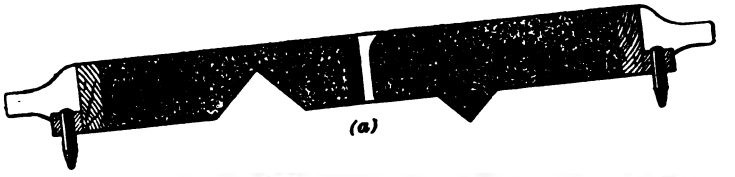
FIG. 18.

use. In starting to make such a board, the pattern is rammed up in a nowel and the joint made as in making ordinary castings. After the joint has been carefully made so as to give it the best possible form (one that will give clean lifts and assist in obtaining finless and true-jointed castings), it is faced with a good oil. The patterns are similarly treated to prevent the plaster from sticking to them. A wooden frame having a bottom board nailed on is then placed as in Fig. 17; both this frame and the bottom board should have plenty of nails *n* driven in them. In this bottom board are two holes *h* for the purpose of pouring in the plaster. Before pouring a plaster mold, the outside of the joints should be carefully stopped up with clay, or else firmly banked up with sand, to prevent leakage. The plaster having been poured in, it is then allowed to set until hard; then the mold board is lifted off and the sand removed from the face of the plaster with brush and water. After the face of the board is finished up smooth and the plaster is dry, it is given a coat of shellac varnish containing lampblack, and when this is dry the board is ready for use. Plaster of Paris is made by heating powdered gypsum, which consists of sulphate of lime and water. The heat drives the water out of the gypsum, leaving a powder that, when mixed with its own bulk of water, forms a creamy paste that becomes solid almost immediately.

In using plaster of Paris, the fluidity of the mixture should be regulated by the thickness of the body required. For thin bodies, 2 parts of water to 1 of plaster makes a good

proportion, but for general work 1 part of plaster to 1 part of water will be about right. The pouring holes should be as large as practicable; for in filling thin places or corners, the quicker the mold is poured, the better. If a mold has any considerable body, it will shrink so much as to require being filled up with more plaster after it is poured. Before starting to pour a mold, therefore, there should be plenty of water and plaster at hand, to avoid any delay after the pouring has begun. With practice, one can estimate very nearly the amount of mixture required to fill a mold; it should be all mixed before starting to pour, especially in the case of light molds. For thick bodies one may partially fill a mold and then complete the job by a second pouring; but generally speaking, plaster of Paris requires prompt handling.

10. Match Plates or Match Boards.—There are cases where **match plates,** as they are termed, will be found of value in expediting the making of joints; their construction is very simple. Fig. 19 shows the mode of constructing a match plate for two patterns, one of which comes wholly below the joint line and the other partly above and partly below it. In Fig. 19 (*b*) the nowel is shown rammed up and the joint made, *P* and *Q* being the patterns. The cope when rammed up appears as seen in Fig. 19 (*a*). The manipulation so far is the same as that required for making a casting from each of the patterns. The next step is to mold the plate portion. This is done by banking sand against wooden strips $\frac{3}{16}$ inch to $\frac{1}{4}$ inch thick. In this way the body of sand *d*, Fig. 19 (*c*), is formed. The thickness of this body of sand should be so chosen that it will make the plate strong enough. The gates are cut as though the casting was to be poured through them. The cope is then closed and the mold poured, the casting being the match plate shown in Fig. 19 (*d*). Fig. 19 (*e*) shows the nowel rammed up, the cope set on, the gate pin *p* in place, and the cope ready to be rammed up. The ends of this match plate extend beyond the flask and contain notches for the



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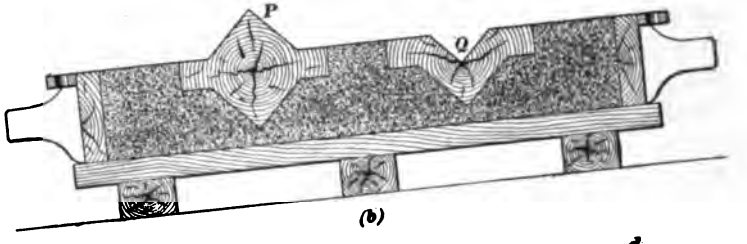

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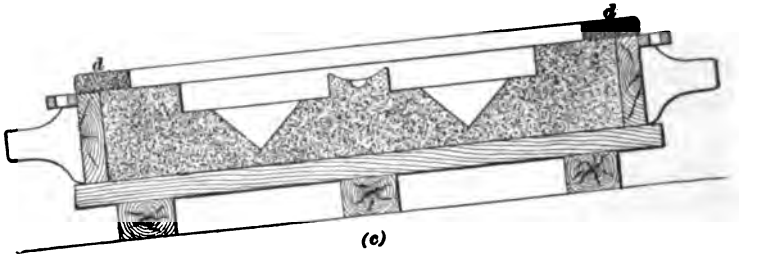
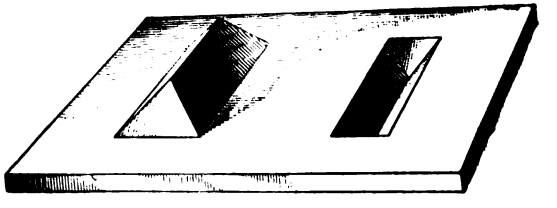
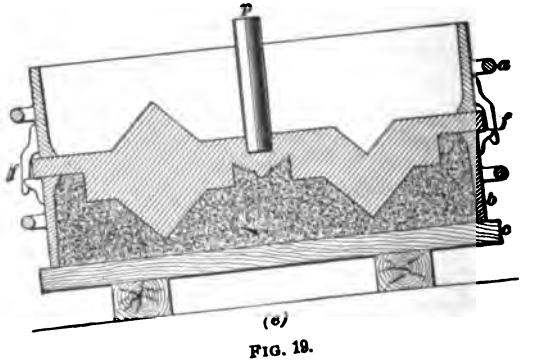


(c)



(d)



(e)

FIG. 19.

flask pins to fit into, so that the mold may come together properly when it is closed. This will be better understood by reference to *f*, *f*, view (*e*), which shows the pins guiding the mold. Should there be any overlapping of joints in the castings produced, the trouble will generally be due to shaky or untrue pins. In making the match plate, as well as in using it, the pins on the flask must be carefully looked after, or properly jointed castings will not be obtained.

Wooden "matches" made by the patternmaker are also used. The match plate or board is of practical use only for castings that have plain outlines and are without sharp corners, cores, or projections.

GAGGERS AND SOLDIERS.

THEIR USE.

11. *Gaggers* and *soldiers* are appliances used in combination with flasks and cross-bars to enable the molder to lift and suspend bodies of sand. This will be better understood by reference to Fig. 20, which represents a cope

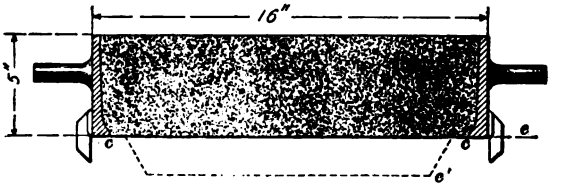


FIG. 20.

16 inches square by 5 inches deep. If this cope were rammed full of good and properly tempered sand, having its joint level with the bottom edge of the cope at *e*, the sand would lift and stay suspended. If, instead of the joint being level with *e*, it is desired to have the cope sand project down into the nowel, as shown by the dotted line at *e'*, where it extends more than ¾ inch below the level at *e*, then

this sand would not be liable to lift with the cope, or if it did, could not be safely suspended without the use of gaggers or soldiers. A body of sand 16 inches square and level with the lower edge of the cope, as at *e*, is about as large a body as can be suspended without the use of cross-bars—such as shown in Figs. 24 and 25. Even with a body 16 inches square, it is necessary to have grooves along the sides of the flask or else projections like *c*, as without one or the other of these the sand will be liable to slide out of the cope. While 16 inches square is given as being the largest area of sand that can be safely suspended, even that cannot be done in all cases.

MAKING GAGGERS.

12. Gaggers are made of cast or wrought iron. Fig. 21 shows the form generally used. They can be made of either square or round iron, and are usually about 4 inches long at the toe *m*, with the shank *n* from 5 inches to 20 inches or more in length, according to requirements, and from $\frac{3}{8}$ inch to $\frac{1}{2}$ inch in diameter or square.

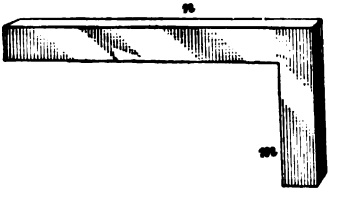


FIG. 21.

In some shops wrought-iron gaggers are used almost exclusively; while in others cast-iron ones have the preference, as they will not spring, are cheaper to make, and have the advantage of being readily broken off to any desired length when shorter ones cannot be found.

Wrought-iron gaggers are useful in work where the toe must be bent to suit slanting surfaces and joints. In some foundries objection is made to breaking cast-iron gaggers, and to avoid breaking them, they are left sticking out of the cope, as shown at *9*, Fig. 26. Gaggers sticking up in this way are liable to be hit accidentally after the cope is closed, and this may result in the loss of the casting. It is bad practice to leave gaggers standing above the surface of the

cope. Cast-iron gaggers can be made to good advantage in open sand by having from four to twelve patterns on

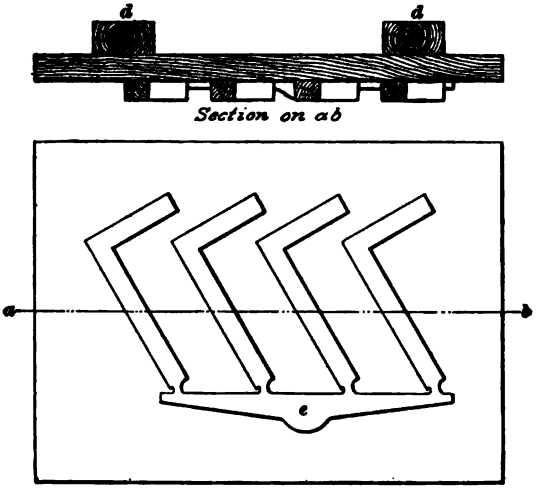


FIG. 22.

a board, as seen in Fig. 22, and pressing the board into a level bed of soft sand by pounding on the battens *d* with a light sledge. When the gaggers are cast, they appear as shown in Fig. 23; they are easily knocked off the runner *e* with a hammer. The wrought-iron gaggers are usually made by cutting straight bar iron into the required lengths and bending the toe *m*, Fig. 21, in a vise, or over an anvil.

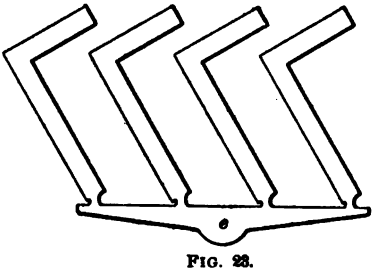


FIG. 23.

MAKING SOLDIERS.

13. Soldiers are merely strips of wood. They can be made by taking a piece of rough straight-grained board, sawed to any desired length, and cutting it into strips of any

desired size. They range in size from a thin strip to one 8 inches wide. Often these soldiers will be nailed to the sides of **cross-bars,** so as to assist in lifting deep bodies of sand. The soldiers, if well sustained between the cross-bars by nailing them or by ramming them firmly between the bars, will lift larger bodies of sand than if gaggers were used over the same area. In using soldiers they must not be placed too near the surface of the casting where there might be danger of the iron breaking the sand away from their surfaces, for if this occurred, the steam and gas from the wood would cause the mold to blow and spoil the casting. Then again, if soldiers are to remain bedded in the sand for more than a few hours, they should be well soaked in water before being placed in position, for if they swell in the mold, they may cause bad castings.

SETTING GAGGERS.

14. The main thing to be kept in mind when setting gaggers is that, bulk for bulk, a gagger is about 4½ times as heavy as rammed sand. Gaggers are used sometimes to aid in lifting bodies of sand that would have a better chance of being lifted were the gaggers omitted; this will be better understood by reference to Fig. 24, in which a body of sand about 3 inches deep is to be lifted. Gaggers set as at *p* will do more injury than good; to be of any service they should be long enough so that at least two-thirds of their length will be between the cross-bars, as at *q*. Then again, where gaggers are expected to lift a heavy body of sand, not only should they come up well between the cross-bars or in the cope, but the sand should be firmly peened and rammed between them.

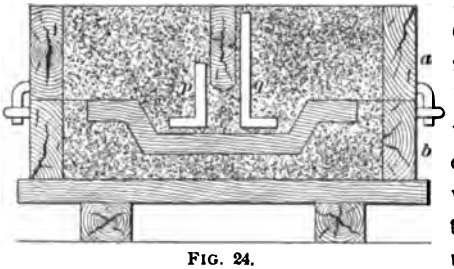


FIG. 24.

SETTING CROSS-BARS.

15. In putting bars into ordinary copes, a space of from 5 inches to 6 inches between each bar will answer for plain work; but for copes that have bars projecting into deep recesses in the nowel, or that have them cut to permit of projections in the cope, different spacing and a different system of barring are often necessary. At *s*, *t*, and *u*, Fig. 25, is shown an objectionable method of setting cross-bars in the cope used for making a long casting of the general cross-section shown at *P*. One objection is that the flat side of a cross-bar is placed parallel with the flat face of the pattern, leaving a poorly supported, thin, flat body of sand *v*. In ramming sand in such narrow **pockets** as at *v*, careful judgment must be exercised; if the sand is rammed too hard, the gases will not escape freely, and scabbing or blowing is likely to result. Another objection to the method

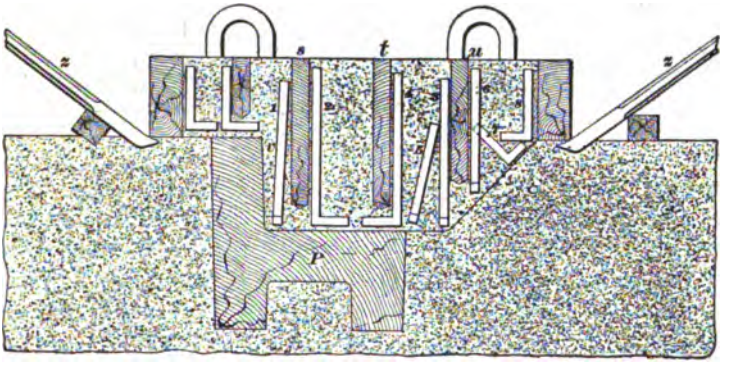


FIG. 25.

shown in Fig. 25 is that where it is necessary to roll the cope over, the thin flat cake of sand is likely to drop off unless securely **rodded,** which involves having straight rods of round iron coming from the face up between the bars. Bars used for lifting sand out of pockets or for carrying hubs or other projections should be arranged so as to have a considerable body of sand around them. This not only lessens the dangers due to hard ramming, or lack of

freedom in venting, but it gives more room for ramming up and seeing what is being done when setting gaggers, etc. Another objection to using bars as at *s*, *t*, and *u* is that the gaggers cannot be set very readily or firmly, and the danger of a "drop out" is greatly increased. For such a job as here shown, the bars should be set across the mold, as indicated by the dotted outline *o o* in Fig. 26. The position of gaggers *1*, *2*, *5*, *7*, and *9*, Figs. 25 and 26, shows lack of

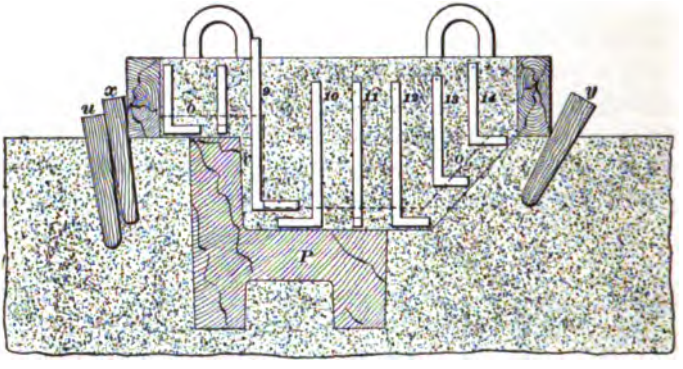


FIG. 26.

judgment. The sand at *7* would be more likely to lift if the gagger was not used, as its length is only about that of the body of sand to be lifted, and iron, as already explained, is a great deal heavier than sand. If bars could not be placed as at *o o*, Fig. 26, and it were necessary to set a gagger as at *1*, Fig. 25, it would be better to keep it about 3 inches higher and reverse the **toe** of gagger *2*, bringing the toe or point under the bar toward the face of the pattern. The position of gaggers *11*, *12*, *13*, and *14*, Fig. 26, in connection with the bars at *o*, *o*, represents good practice. Gagger *9* should be reversed, having its toe turned toward the face of the pattern, while *10* should be brought forward and have its toe almost touching the face of the pattern. If the cope is to be rolled over, more gaggers (*13* and *14*) should be used as the height of the ramming increases. The

points of gaggers against the surfaces of flat bodies of sand cannot do the harm that gaggers can when set as at *1* and *9*, by not having good support and by producing soft spots in the mold.

DRIVING STAKES AND STARTING THE JOINT.

16. Fig. 26 is also used to show right and wrong methods for staking copes that are used over bedded-in patterns. Stakes should be driven almost parallel to the side of the cope, as shown at *x*; it is bad practice to drive them at a considerable angle, as shown at *y*; a stake driven in this manner is liable to cause poor lifts and overshot castings, because of the great angle it makes with the surface of the floor. In staking flasks for ordinary work, at least two-thirds of the length of the stake should be driven into the ground. Sometimes, to insure greater certainty in large work, it is best to drive one stake behind another, as illustrated by *u* and *x*. To assist in the lifting of such deep copes as shown in Figs. 25 and 26, iron starting bars can sometimes be used, as shown at *z*, *z*, Fig. 25. It is important that the cope be started properly; for if it is started so as to raise one side before the other, or if it is started with a jerk, the most careful ramming and use of gaggers will be of little avail in giving a good lift. Where two or more men are required to lift the cope, it is often a good plan to first raise it an inch or two by raising each corner alternately from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch and inserting a wedge to hold up the corner as it is lifted, or it may be advisable to raise one side of a cope at a time, lifting it only a small distance at once; the distance can usually be increased at each succeeding lift.

FINISHING THE MOLD.

WORK REQUIRED AFTER DRAWING PATTERN.

17. As a rule, all molds require more or less finishing after the pattern has been drawn, bench-work castings requiring the least of any. Some light-work patterns are so

finely made and gated that the cope may be closed as soon as the pattern is drawn, there being no finishing whatever required; in heavy work, however, the reverse is usually true. In some cases it may take longer to finish a mold than it took to ram it. This may be due to the intricacy of the design, or to bad work in drawing the pattern, or it may be due to the manner in which the mold was rammed up.

CARE AND SKILL IN RAMMING.

18. Two molders may ram up the same pattern in the same flask, and yet one may take twice as long to finish the mold as does the other. As a rule, the greater the care, skill, and time bestowed on ramming, the less time is required on finishing; the skilled and careful workman, generally speaking, so rams his mold as to require the least time in finishing.

In the case of many heavy-work molds the inserting of a nail or rod at the corners and flanges when ramming will render them less liable to start or break when drawing the pattern; and there are but few such molds in which care in ramming will not prevent their having soft places that require to be patched. In some cases, the soft places that occur from careless ramming may be so extensive as to cause large portions of the mold to break and fall down while the pattern is being drawn. In the ramming of copes especially, there is an opportunity to save subsequent labor in finishing. Some molders use so little skill and care in ramming the cope, that when it is lifted off, the sand will be soft under all the cross-bars. Where this occurs, the soft places must be pressed down solidly with the fingers, sand filled in firmly by hand, and rubbed off level with the rest of the mold by using a finishing block or straightedge before the surface is ready to be sleeked with the trowel. All of this extra work can be avoided by careful ramming. A cope that is so rammed that when lifted the sand under the cross-bars has to be worked over to make it solid will rarely give as good and true a surface as would otherwise be the case.

NAILS AND RODS AT JOINTS AND CORNERS.

19. A judicious use of **nails** or **rods** in ramming and finishing molds may prevent many castings from being defective. It is possible, however, to use them too freely or improperly. A nail should not be used as seen at *m*, Fig. 27, as when driven in this manner, it only adds weight to the edge of the mold, instead of giving it support to keep it from **dropping.** The proper way of using such nails or rods is shown at *n*. Here the nail is driven in such a way as to take it away from the face of the pattern into the body of the sand, where it can have a firm hold and assist in keeping the edge from dropping.

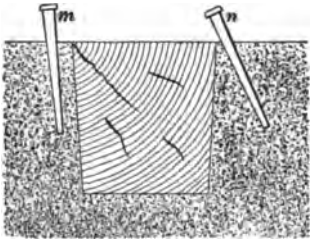


FIG. 27.

PATCHING THE MOLD.

20. Often the mold is more or less broken in drawing the pattern. Whenever practicable the mold should be mended with the hand, and then smoothed off with a **finishing block** or straightedge to as nearly as possible the

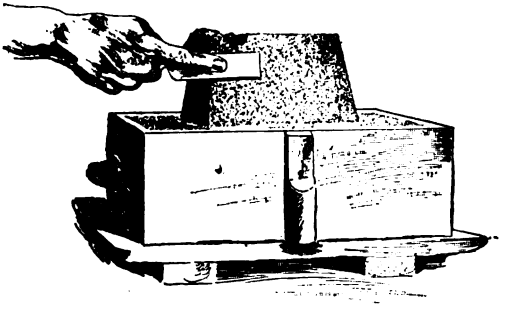


FIG. 28.

proper form, before a trowel or other finishing tool is used. Many molders **patch** such places with a trowel; but when one takes sand on a trowel and presses it on to the mold, he

gives the face of the patched part a smooth surface, with which the next trowel of sand will not unite as well as when the broken parts are built up by using only the hands. The objection to patching with a trowel is that the patched part may be easily loosened and drop if the cope is slightly

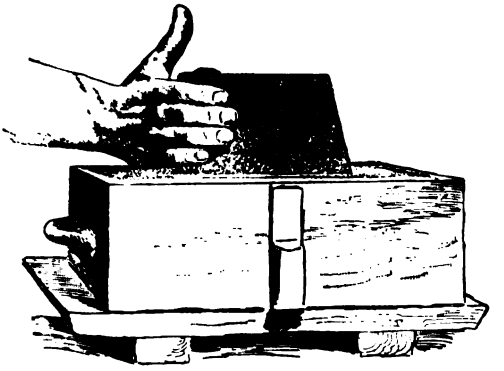


FIG. 29.

jarred; or it may be washed off by the friction of the inflowing metal when the mold is poured. Fig. 28 shows the molder's hand patching a broken corner with a trowel, while Fig. 29 shows the hand being used to get the part in proper form before the trowel is used.

SWABBING BROKEN CORNERS.

21. Many molders before starting to patch a broken mold freely wet the surface with water, thinking thereby to make the sand stick better to the broken body. Unless the broken surface is drier than the rest of the mold, it should not be moistened. If it should require moistening, however, the mouth or one of the spraying devices shown in Figs. 15 and 16 should be used; for when the water is put on with a swab or sponge, it is liable to make the surface of the broken part too wet, and this may do more harm than good.

MOISTURE IN MOLDS.

22. In tempering green sand, it is given a certain degree of **moisture,** and when this is too great the volume of steam created by the hot metal in the mold, during the pouring, may become dangerous. The sand will permit a certain amount of steam to pass through it without harm; but when a molder makes the under surface of his mold too wet, and then fills the mold with molten metal, the metal rapidly heats the sand to a temperature sufficiently high to change the water to steam, and this steam will liberate itself in the line of least resistance. If the wet portion of the mold has been well vented, the steam may pass off through the sand, but the chances are that the line of least resistance will be through the liquid metal. If the steam passes through the metal, it is likely to have enough force to raise (in part, at least) the body of sand that is covered by the metal. If it does this, we may expect lumps or scabs on the casting, making it defective. Or again, there may be so much steam created that it will start the mold **blowing,** and this may result in losing the casting; or worse still, in throwing the iron out of the mold at the risk of life and property. As a rule, it is safe to mend a broken part of the mold without first wetting it, and then after the patching is completed, to take a swab and wet the surface of the finished part, in some cases quite heavily, and still have no injurious results from steam. This is owing to the fact that in order to escape, the steam will not have to raise a body of the sand. The steam being created at the surface, the portion that does not pass off through the sand has only the iron to pass through in order to escape. In doing this, it may make the casting blow to some extent, as it would if the steam had come from the lower parts of the mold; but if the blowing is not too great from this cause, the casting will not be injured.

An illustration of what is to be expected from steam confined under the surface of the mold is shown in the fact that one can cover the surface of a body of liquid metal with water without any injurious consequences, the reason

being that the steam is created on top of the iron and has simply to pass off into the atmosphere in being liberated. Let one try, however, to place the same body of water in the bottom of a ladle and then pour liquid metal in on top of the water; the result will be an explosion that will drive all the iron out of the ladle, and possibly seriously burn those near by. Dampness can only exist with safety so long as it is on the top of metal; if it occurs underneath the metal, serious results may be expected. If the molder will bear this principle in mind when swabbing any part of his mold, he will have very little trouble with scabs or blowing as a result of an excess of moisture.

Another evil resulting from the use of too much water in finishing a mold lies in its hardening the metal at the point of extra dampness. The edges of castings can be made so hard by extra dampness in the sand at such points that a file will not cut them. Another effect of excessive dampness is to give the iron an extra amount of combined carbon at such points; this alteration of its physical nature may cause a casting to crack when cooling, or break in pieces when put into use.

VENTING PATCHED AND SHARP BODIES OF SAND.

23. It is always well to vent patched parts of a mold with a $\frac{1}{16}$-inch vent wire, for usually the patched sand will be harder and damper than the rest of the mold. Again, in many large molds having corners, projections, etc., it is a good plan to pass a fine wire from the face downwards into the body of the mold to a depth of from 4 to 6 inches. These fine-wire vents will provide a means of escape for the gases to the larger vents, and if made about 1 inch apart over the surface most likely to scab, that evil will be avoided. Many molders make a practice of venting almost every sharp corner or projection in large molds, and although this takes time, yet it pays in the end, for it is seldom that any delicate portion of molds so vented give scabbed castings. To prevent such fine venting breaking

the surface of the molds, the vent wire is run through the opening between two fingers, as shown in Fig. 30. The tops of the fine vent holes are stopped up by pressing the fingers or palm of the hand over them, and then going over the holes with a little fine-sieved sand, rubbing it into them with the hand; after this, the surface is neatly sleeked and then dampened lightly with a swab, or sprayed. The success of some molders in getting large castings free from scabs, etc., is due in part to their habit of using the fine vent wire at corners when finishing their molds.

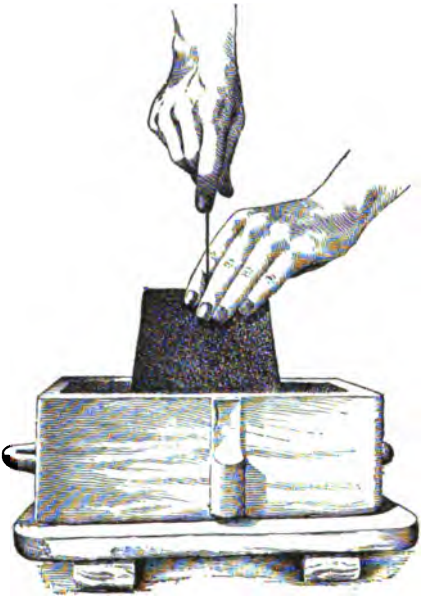


FIG. 30.

USING THE TROWEL.

24. Considerable skill is required in handling a trowel properly. When one first uses a trowel, he is liable to dig into the sand and do more harm by loosening the sand than he does good by pressing it down to a solid smooth surface. The trowel should never be kept flat on the body being sleeked, as in Fig. 31. The proper way to use it is to raise one edge slightly, as at *d*, Fig. 32; it is here, however, elevated an excessive amount for the purpose of illustrating the idea more clearly. The trowel should have its forward edge raised only about $\frac{1}{16}$ inch, this being just enough to keep it from digging into the sand and yet not leave a flat face on the sand. If one is an expert, he may, in many

cases, sleek green-sand surfaces with the whole flat surface of the trowel bearing on the sand.

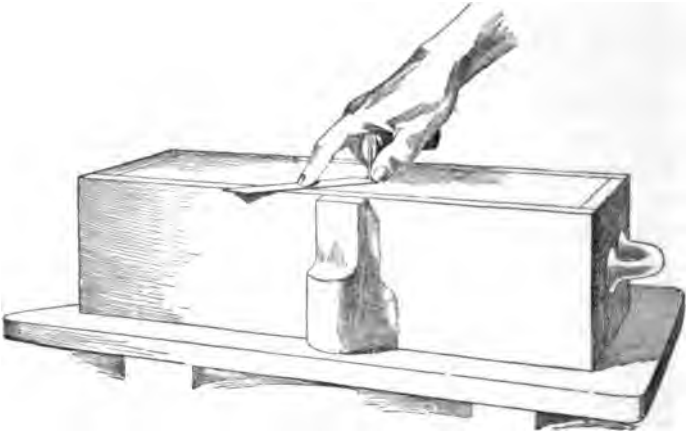


FIG. 31.

In handling a trowel, the first finger should project as far on the blade as convenient, so as to give a pressure to the

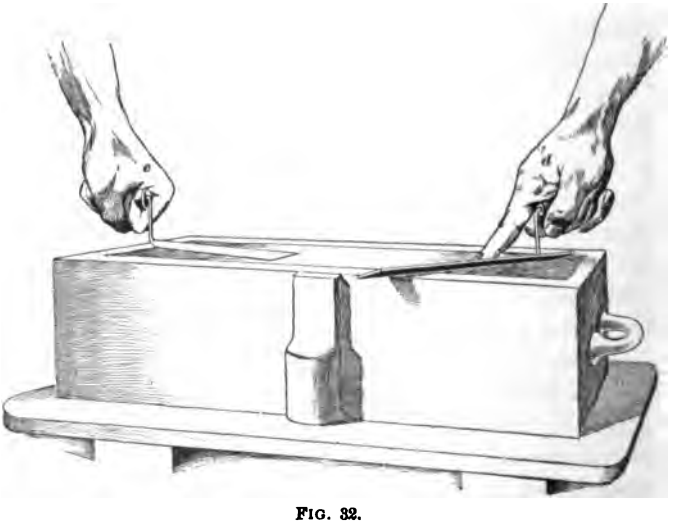


FIG. 32.

blade, as seen in Fig. 31; a novice will usually grasp a trowel by the handle, as seen at *e* in Fig. 32.

A facing of dry blackening or silver-lead dust should rarely be sleeked on the surface of a mold with the flat of a trowel; for if the blackening does not stick to the trowel, it is liable to loosen in such a manner as to lift when the mold is being poured and cause what are called **blackening scabs** to appear on the casting.

USING THE SLEEKING TOOLS.

25. When sleeking wet blackening on cores or molds (skin-dried, dry-sand, or loam work), the trowel must be kept tilted. If at any time the flat face of the trowel or any other finishing tool touches the wet blackening, it will stick to it. Not only must the finishing tool be tilted, but it must be kept in motion, for if still an instant, the wet blackening will stick to it. Considerable skill is required in sleeking wet blackening, and much experience is necessary before one can handle finishing tools in such a manner as not to start the blackening, the effect of which would be to cause blackening scabs on the casting. Some wet blackenings are so difficult to sleek that it is necessary to keep constantly dipping the tools in water, in order that they may slide more easily over the blackened surface.

OTHER FINISHING TOOLS.

26. A molder should have a good set of **molding tools.** Some shops demand that a molder be well equipped with tools; in fact, they often go so far as to require the molders to have tools that will fit nearly every variation in the shapes of edges and corners that may exist in their patterns, and if these shapes are out of the ordinary line manufactured by regular toolmakers, they will have the special tools made.

The trowels, lifters, and double-enders are usually made of steel, while the other tools are often made of cast iron and brass. Brass tools will sleek wet blackening better than those

made of iron or steel, although if steel tools are nicely made and finished, many molders can do better work with them than with those made of brass. Figs. 31 and 33, and also Fig. 41, *Foundry Work*, Part 1, show the ordinary finishing tools. These can be obtained from dealers, in different sizes. A tool box especially designed to hold tools in such a manner that any one of them can be readily found is very desirable, and the tools should always be clean and in good order, ready for use.

The names of the tools shown in Fig. 33 are as follows:

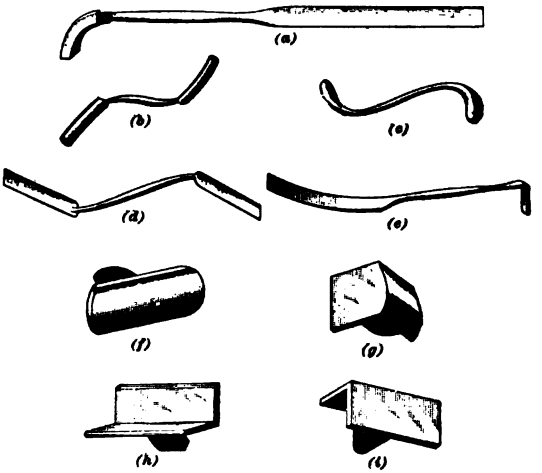


FIG. 33.

(*a*), flange and lifter; (*b*), flute; (*c*), bead; (*d*), double square; (*e*), Jankee No. 1; (*f*), pipe slick; (*g*), half-round corner; (*h*), inside square corner; (*i*), square corner.

SLEEKING AND PRINTING DRY BLACKENING.

27. After the surface of a mold has been finished, it is often necessary to "dust on" blackening (or to rub it on with the hand) and then to sleek it down solidly with the same tools that were used in finishing the surface of the

sand. For heavy castings, it is best to rub on the blackening with the hand; especially is this necessary when putting it on the sides of molds and copes that cannot be rolled over. In a great variety of work, the blackening can be shaken out of a cheese-cloth or other thin cotton-cloth bag, as in Fig. 34; or it can be scattered by the hand in the same way that parting sand is spread. After a mold has been coated with dry blackening, it should be sleeked as soon as can be conveniently done. If there is any delay, the blackening is likely to absorb the moisture from the sand; with some blackenings it will then be difficult to sleek them without their sticking to the trowel, the result of which will be a badly finished mold that may cause blackening scabs. Where trouble is caused by the blackening sticking to the tool, it is best to dust on a light coat of charcoal over the top of the heavy sticky blackening. Charcoal dust is very light and is slow to absorb moisture; this makes it an excellent material to aid in the sleeking of sticky grades of blackening. Where charcoal has been used, bellows are necessary to blow off all the dust that does not adhere to the surface of the mold; if this is not done, the loose dust will run before the metal when the mold is poured, and gather in lumps. In fact, where it is desirable to have clean, sound castings, it does no harm, whatever may be the grade of blackening, to use the bellows to blow off the dust, provided the face of the mold is not broken by the force of the blast.

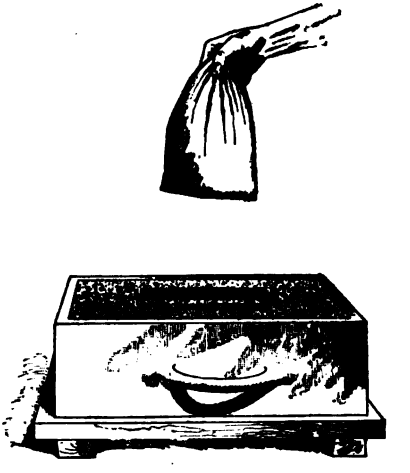


FIG. 34.

It is chiefly in medium-weight and heavy castings that it is found necessary to sleek dry blackenings. In light work,

another plan, called **printing,** is largely followed. This consists in shaking the blackening (out of a bag) evenly over the whole surface of the mold and then setting the pattern back carefully into the mold; the pattern is then rapped down lightly over the whole of its surface and in this way pressed into the blackening dust. It is again rapped lightly (to loosen it in the mold) and then withdrawn. If the above is properly done, the loose blackening dust will have been pressed down solidly on the face of the mold and will give form to the most delicate imprint of the pattern. In printing patterns, the molder generally has at least two bags; one holding a heavy blackening that he will shake on first, the thickness of this first coat being sufficient merely to cover the face of the mold, only about $\frac{1}{64}$ inch. The second bag will contain charcoal dust, or some other light grade of a specially prepared blackening. As soon as the dust from the first bag has settled, the second bag will be used, after which the pattern is "printed back," as described. In doing this, the pattern must be perfectly dry. This is very important, for if there is the least moisture about the pattern, the blackening will stick to it when it is withdrawn from the mold. After a pattern has been imprinted, bellows are often used to blow off any blackening dust that may not have been firmly pressed on to the surface of the mold.

SKIN-DRIED MOLDS.

GENERAL REMARKS.

28. Many large castings that it was formerly thought impossible to make except in dry-sand or loam molds are now made in green-sand molds by **skin-drying.** Skin-drying is also practiced with lighter work for the purpose of giving green-sand castings the surface and color of dry-sand ones.

It may be advisable to skin-dry some molds because of

the nature of the sand used; this may contain too much clay, or it may be of such character that it would not otherwise withstand the heat and wash of the metal. The purpose of "skin-drying" is to give green-sand molds a hard surface, devoid of moisture as far as possible, and like the hard and dry surface found in dry-sand and loam molds. For this purpose special physical characteristics are required in the sand that is used for the **facing**, as common heap sand can be used only for the **backing**. The facing sand should be of a loamy open nature, hardening only when heated, and also sufficiently porous to permit the metal to lie against its surface without bubbling or boiling. When unable to obtain the right grade of sand for making facing, the ordinary grades may be used if mixed with flour, beer, molasses water, or clay wash. When flour is used, the usual proportions are 1 part of flour to from 20 to 30 parts of sand, according to the nature of the latter. When flour is used in the sand, care must be taken in drying the mold, for if the heat is great enough to burn the flour, it will cause the surface of the mold to crumble. The beer, molasses water, or clay wash may in some cases be used for wetting sand that has been mixed with flour, or the flour may be omitted and the sand sufficiently strengthened by the aid of the washes. Again, some sands, on account of their closeness, may require to have a sharp sand mixed with them. Some localities possess molding sand naturally adapted to skin-drying, while others do not, and, therefore, in the latter, more or less "doctoring" will be necessary to make the sand serviceable. The thickness of the facing used against the pattern generally ranges from 1 to 2 inches. After the facing sand has been banked against the pattern, common heap sand is used for a backing, and the mold rammed in the manner generally followed in green-sand work.

The facing for skin-dried molds is, as a general rule, used a little damper than facings would be for common green-sand work.

In cases where the sides of molds are very deep, and very

heavy or deep copes are used, it is often well to ram up ½-inch to ¾-inch rods with every other course, as at Nos. *1* to *10*, Fig. 35. Where the copes are skin-dried,

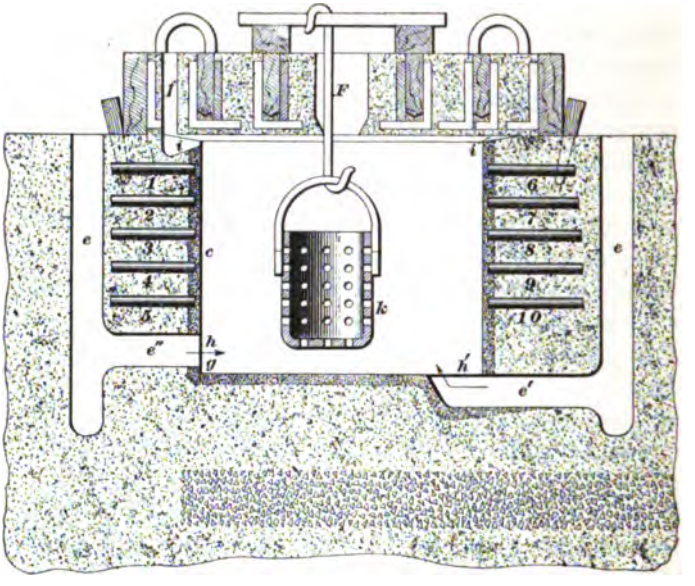


FIG. 35.

they should, as a general thing, be very closely gaggered; and with some grades of sand, the surface should have nails between all the gaggers with the heads coming even with the face of the mold and covered only with the blackening; for if this is not done, the dried crust on the surface of the mold may easily drop off. Not only is this practiced with copes, but in some cases molders will nail the side of nowels that are over 6 inches deep as a protection against the dried crust falling away from its green backing. The gates and portions of the mold where the metal first enters are generally the parts that should be well nailed, for in skin-dried molds if the surface once becomes broken it soon washes the crust away, after which the material offers no greater resistance to the rushing metal than would so much dry dust.

In finishing the joints of skin-dried molds, it is essential that they be **shaved** as at *i*, Fig. 35, so as to prevent their crushing when the copes are closed, for the least pressure on the joint at the edge of such a mold may readily cause a **crush.** There is no class of molds that requires more delicacy in handling, for the surface is only a crust about ½ inch thick that has but little union with the body of the mold, and may easily be separated from it by any jarring. Some molders will not trust to the nails for holding the portions of the mold surrounding the gates, but instead make cores the shape of that part of the mold and ram them up with the pattern. This is the best method for preventing skin-dried molds from cutting at the gates.

FINISHING A SKIN-DRIED MOLD.

29. After the mold has been made and its surface nailed over, as just described, it is finished by wetting the entire surface with beer or molasses water. This is done lightly by means of a camel's-hair or other soft brush. After the surface has been moistened it is sleeked up with finishing tools, as in finishing any green-sand mold. Where molds are very large, they are moistened and finished in sections, for if all the surface of a large mold were moistened at one time, portions of it would be too dry to finish well by the time the molder reached them; when there is more than one molder working on a job, this precaution may not be necessary. The mold having been sleeked with the finishing tools, the next proceeding is to blacken its surface, which may be done in one of two ways. One is to blacken the mold in the same manner that a dry-sand or loam mold is blackened; the other is to rub the blackening on dry in the dust form and then, after sleeking it as in Art. **27,** to moisten the surface heavily with molasses water or beer wash (the former is preferable), applying the liquid with a soft brush. Rubbing the blackening dust on is only necessary on the sides of the mold, as a bag can be used to shake

it on the bottom. These two methods of blackening may often be used to advantage on the same mold. The plan of rubbing the blackening on dry and then going over it with the molasses water or beer wash, does not dampen the surface as much as when it is blackened with an all-wet blackening, as in the case of a dry-sand or loam mold. The reason why these two plans of blackening will sometimes work well together is because in skin-drying the mold with fire-pans or sheet plates, there are some parts that will receive more heat than others.

By exercising care and judgment in dampening the sand and in blackening, all parts of the mold may become dry at about the same time; if the work is done in such a way that one part dries before the others, it may burn. In blackening the surface it should be done as smoothly as possible, so as to avoid the necessity of much sleeking. By sleeking the wet blackening, a smoother casting may be produced; but unless it is carefully and skilfully done, there is more or less danger of the sleeking causing scabs. In putting the blackening on, it can be used thin enough not to be "streaked," and with care in using a camel's-hair brush, no streaks need be shown, so that the castings can be made nearly as smooth as if the blackening were sleeked, and the danger caused by sleeking can be avoided.

DRYING A SKIN-DRIED MOLD.

30. General Directions. — In drying these molds, considerable judgment is required, for a scheme that will work well with one mold may not answer for another. That method must be adopted which is best suited for the work in hand. For example, some molds, such as those for anvil blocks, etc., may be dried by setting a **fire-pot** in them as shown in Fig. 35, where the cope is shown being dried above the nowel. Sometimes the mold may be of such a form as to require a flat or square pan instead of this cylindrical kettle here shown; and with some molds this plan will

not answer at all, because they are so shaped that kettles or pans cannot be used in them. These molds may be such that their surfaces can be dried by laying sheet-iron plates, perforated with small holes, over them, and placing a fire upon the plates; but this is a plan rarely used where kettles or pans can be employed.

The fuel commonly used in these appliances is charcoal; the fire should be mild and steady, especially at the start, since too strong a fire is apt to blister the face of the mold. Sometimes the cope and the nowel may be dried together by having the cope propped up clear of the nowel, and then heating between them by means of fire on perforated plates or in pans. Again, the mold may be such as to permit of its being closed while being dried, the riser and gates being left open to let out the steam, as shown in Fig. 35. In the illustration the upright pouring gates are marked *e*, the inlet gates *e'* and *e''*, the riser *f*, the feeder *F*, and the fire-kettle *k*. The dried crust *c* is shown shaded.

Natural or artificial gas may be used for drying molds. The gas is conveyed to the mold in a rubber tube having a piece of gas pipe in the end, and then burned against the face of the mold.

Green-sand cores or bodies forming the interior of molds are generally skin-dried by placing them in an oven and keeping the heat mild and uniform. To ascertain if a mold or core is skin-dried deep enough, it may be tested by cutting a small hole in the surface, or by pressing the surface with the fingers. The most difficult places to dry by means of kettles or pans are the corners of a mold, as at *g*, Fig. 35. The sides of some molds might be baked and the binding material burned to ashes before the corners could be dried. To get the corners dry it is often necessary, after a kettle or pan fire has been taken out, to place hot coals or hot irons around in them to get them dry. It is here that the advantage of gas or hot air is apparent, as by either of them the heat can be directed to any given spot until it is thoroughly dried.

Any one wishing to acquire skill in skin-drying molds

should begin on a small scale, as he is liable to make many blunders at the start.

31. Gas Burner for Drying a Mold.—A good plan to follow when drying molds by gas is to substitute a **Bunsen burner** for the pipe. The objection to using an open pipe burner in the foundry is that usually a $\frac{1}{8}$-inch or $\frac{1}{4}$-inch pipe is used, which is not only wasteful of gas, but its flame deposits such a coating of soot on the face of the mold that comparatively little drying is accomplished.

The burner illustrated in Fig. 36 has been designed and used for this class of work; it is also well suited for any work requiring a gas heater. As ordinarily constructed, the burner consists of a piece of $\frac{1}{2}$-inch pipe *a*, 6 inches long, threaded at one end and screwed into a reducer *b*, as shown in Fig. 36. The reducer has five $\frac{1}{4}$-inch holes *c* drilled into it to admit air. More holes may be drilled if required, and if, on the contrary, it is found that too much air is being furnished, some of them may be plugged up with wood or, better, by tapping the extra ones and putting in $\frac{5}{16}$-inch screws. A $\frac{1}{4}$-inch pipe about 2 feet long is threaded on one end and closed with a plug driven or screwed into it. A $\frac{1}{16}$-inch hole drilled lengthwise through the plug *e* furnishes the right proportion of gas to the burner. The plug *e* should extend at least $\frac{1}{4}$ inch past the holes *c*.

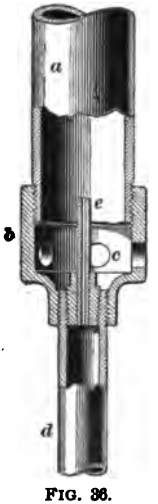


FIG. 36.

When constructed in this manner the burner may be used upside down or in any other position. It gives no light, but a great deal of heat.

GATING A SKIN-DRIED MOLD.

32. In **gating** skin-dried molds, the method that will induce the least friction between the flowing metal and the surface of the mold is, as a rule, the best to adopt. In Fig. 35 are shown two methods of gating that can be used

with a large variety of molds. With a gate like that marked e'', the metal will flow in as shown by the arrow h. Such a gate as this will cause great friction between the metal and the face of the mold, and unless the whole surface fronting the inlet gates is nailed very closely, with the heads of the nails even with the bottom face of the mold, the casting will scab at that point. Instead of nails, strong cores may be used to form all the surface fronting the inlet gate, thus preventing scabbing at that portion of the mold.

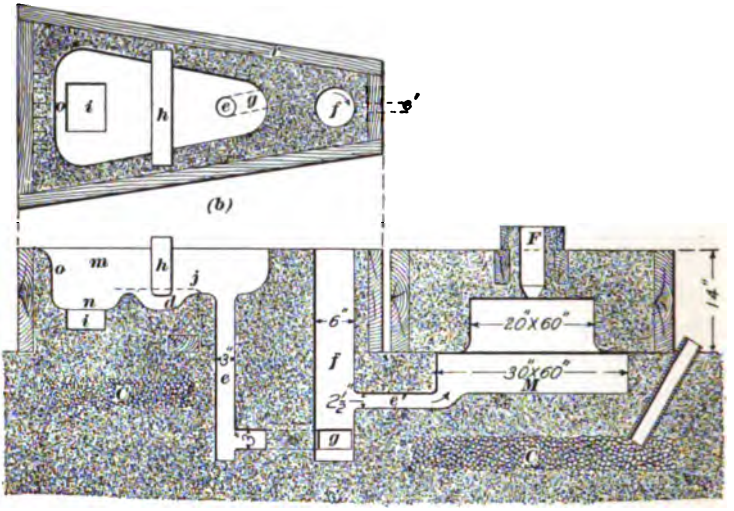
The best kind of gate to use for such work is shown at e' on the right of the illustration. Here the metal, on entering the mold, will come up from the bottom, as at h', and flow gently all over the face of the mold, causing little or no friction that might cause scabs. This form of gate is easier on the face of a mold than any other. It can be applied to a large class of molds. The only objection to it is that it does not distribute the dirt created in the pouring runner and gates or that may come from the scum of the ladle. As a rule, all such dirt will collect in a body and stay floating right above the inlet h'. In molds having cores or projections that will catch dirt and confine it in the parts especially requiring solid metal, this class of gate (e') would be undesirable. With an inlet gate as at e'', the dirt is divided into fine particles and distributed to all portions of the casting, which, in some cases, may be preferable, even though there is a scab created in front of the gate.

GATES FOR MOLDS.

POURING GATES FOR CATCHING DIRT.

33. The gates shown in Fig. 35 are very apt to collect and hold the dirt in one spot, but there are methods in use that serve to considerably lessen the amount of scum or dirt passing into these gates. Fig. 37 shows some of these methods, which may be modified as deemed desirable. In pouring a casting with a system of dirt catchers

(commonly called **skimming gates**), such as in Fig. 37 (*a*), the metal first flows into the depression at *d*, filling it so



(*a*)

FIG. 37.

that the core seen at *h* holds back much of the dirt or scum coming from the ladle. From *d* comparatively clean metal should pass down *e* through *g* to *f*. In the plan (*b*) it will be observed that the connection *g* between *e* and *f* is led to one side of the latter so that the metal is given a whirling motion on entering *f*, which causes the scum and dirt to rise up into *f*, and insures that comparatively clean metal passes through *e'* into the mold; *e'* here corresponds to the inlet gates *e'* and *e''* in Fig. 35. To make this form effective the inlet gate *e'*, which leads the metal into the mold, must have a smaller area than either of the other openings. This is necessary so that the flow through *e'* will be "dammed" back and thus keep the riser *f* full of iron. Keeping *f* full of iron causes the dirt to float on top of it; whereas, did the metal in it descend to the level of *e'*, this dirt would then pass into the mold.

The sizes of the various gates are given so as to afford an

idea of proportions that work well. The parts marked (other than those already alluded to) are *m*, the pouring basin; *i*, a core; *r*, the runner box; and *F*, the feeding head. With such a system of skimming gates, the under inlet gate *e'*, Fig. 35, can be used with very little risk of having much scum or dirt pass into the mold. If the molder desires to decrease his labor in making such a system, the core *h* and depression *d* can be omitted and a level bottom used, as indicated by the dotted line *j*, Fig. 37.

A study of Fig. 37 will show that intricate work is involved in this system; and that unless the molder exercises care and skill, there will probably be more dirt created by the sand washed from the corners and surface of the gates than would have flowed into the casting had there been but one straight gate and no skimming gates at all.

SKIMMING GATES FOR MEDIUM AND LIGHT CASTINGS.

34. It may be stated here that skimming gates are arranged on the principle that all scum or dirt has less specific gravity than iron, for which reason it will float to the highest point that it can reach. In arranging skimming gates, some part is constructed to catch and hold the dirt as it rises to the surface of the flowing metal before it can enter the mold. The plan of skimming gates just described is for heavy castings; Fig. 38 illustrates a method

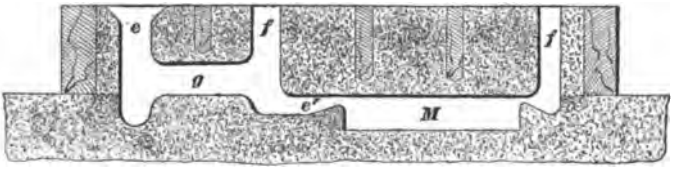


FIG. 38.

suitable for medium and light castings. In this the sand is rammed around two sprue pins to form a pouring gate *e*, and dirt riser *f*; a dirt-collecting channel *g* is then cut between them. The higher and longer this channel *g* can be

made, the better dirt collector it will be. The metal having passed *g* flows on through *e'* to the mold *M*. In flowing from the gate *g* to the mold *M*, the scum or dirt in the metal, as it rises, is caught and held in the upper part of the channel *g* and dirt riser *f*. Sometimes the channel *g* is cut on a straight line to *f*, and sometimes on a curve, as at *g* and *f*, Fig. 37. If this is done properly, lumps of dirt should be seen whirling on the top of the metal in the dirt riser *f*, Figs. 37 and 38, and when breaking the channel *g*

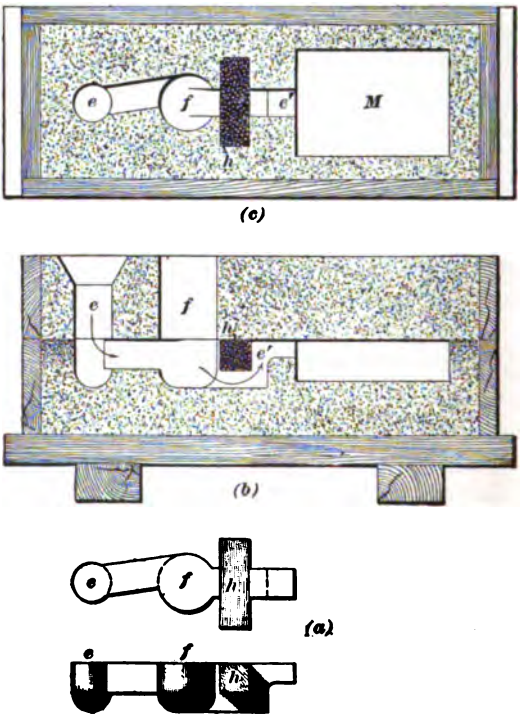


FIG. 39.

after the metal has cooled, dirt should be found in its upper part.

It is often desirable to have skimming gates for light work arranged so as to save as much labor as possible. This may be done by using the appliance seen in Fig. 39 (*a*), which is

a small pattern so arranged that it can be rammed with the pattern in the nowel of small boxes or snap flasks. Two patterns or sprue pins are used to form the sprue *e* and riser *f*. When the mold is finished, the skimming gate should appear as seen in views (*b*) and (*c*), a small core being used as shown at *h*. The metal on being poured into the gate *e*, flows into *f*, with a **whirling motion,** and in going to the mold passes under the core placed at *h*, whence it passes through the gate at the entrance *e'* into the mold, as shown by the arrow.

The advantage of this skimming gate is that it can be formed very easily by means of the core *h*, which is set into the mold after the skimming-gate pattern is drawn. This core, being arranged to settle deeply into the gate, causes the iron that enters the mold to be taken from the lowest point of the skimming gate, which insures clean metal going into the mold. It is a simple device, but very effective in its results.

TOP-POURING SKIMMING GATES.

35. Another form of skimming gate is that used in **top-pouring,** shown in Fig. 40. This is applicable to a great variety of work in both light and heavy castings. In constructing such gates, a **pouring basin** *m* is made; the metal enters the mold through a gate or gates *e*. By a quick dash of the metal from the ladle at the start when pouring, and by then keeping the pouring basin full until the flow-off risers show that the mold has been filled, the dirt will stay on top of the metal in the pouring basin, leaving clean iron to pass into the mold. It is only when beginning to pour that dirt should have any chance to enter the

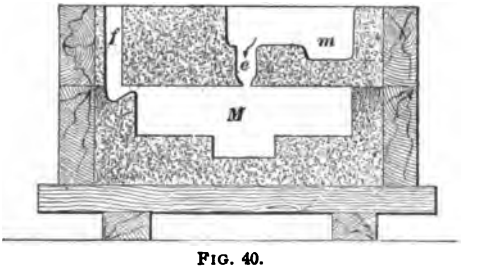


FIG. 40.

mold; and this is true to a greater or less extent of all forms of skimming gates. There are many forms of skimming gates, but those shown in Figs. 37 to 40 should be sufficient to indicate the principles involved.

DIRT IN CASTINGS.

36. After scum or dirt has entered a mold, it must locate itself somewhere. Its natural tendency, on account of having a less specific gravity than iron, is to rise to the top of the mold; but there are conditions that at times prevent this. When iron enters a mold, it rapidly loses its fluidity, and for that reason if dirt drifts to the side of the mold, it is liable, on account of the dullness of the metal, to stick there and let the metal flow over it. Again, molds often have projecting cores that, when the metal rises to the under side, catch the dirt and retain it.

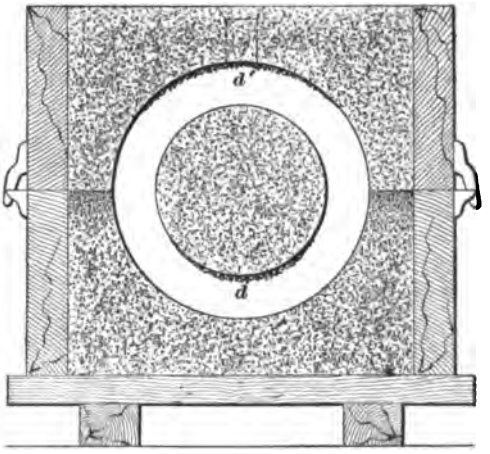


FIG. 41.

If we consider the case of cylinders or pipes cast horizontally, we shall find that the scum or dirt will lodge as seen at *d*, Fig. 41, and what passes this point will rise to the top and stay at *d'*. On this account it is often necessary, if the inside is to be bored out, to leave extra stock for finishing at *d*. If the castings are columns for supporting buildings, or similar pieces, it would be wise to make them thickest on the top or cope side at *d'*, to allow for the weakness that the dirt might cause at that point. Even with the same amount

of dirt at *d* and *d'*, and with the nowel and cope parts of the casting of the same thickness, the cope will be the weakest side of the casting, as there is less pressure at that point of the mold to make the metal solid.

POURING BASINS.

37. In making a mold there are few things that require greater care and skill than the pouring basin. Here the greatest amount of friction, rush, and washing-out effect of the metal is produced; and if the basin is not well made, it will be easily cut by the falling metal. If the basin once starts to cut, considerable damage may result before the mold is filled. A molder may slight the rest of his mold and yet have his castings come out so that they will pass inspection, but any carelessness or ignorance in making basins, runners, or gates will cause trouble. In pouring a mold, the iron first drops from the ladle into the basin, from which it runs with more or less velocity into the upright sprues or runners, and from them into the gates that lead into the mold. With the exception of that portion of the mold into which the iron enters or drops, there is very little agitation of the metal as it gradually rises in a mold, compared to the rush and spattering that exists (more or less) in the pouring basin. When making these basins, extra care should be taken to see that the sand has been well mixed and riddled before it is shoveled into the basin box. The use of poorly tempered sand for making basins has often caused bad castings. Some molders shovel a little sand into the box to form the bottom of the basin and then tramp it with their feet or pack it with a rammer, after which they press sand against the sides of the box with their hands to give shape to the pouring basin; this is a very bad practice to follow. To make a reliable basin, the box should first be evenly rammed full of sand, after which the shape of the basin can be dug out with a shovel or trowel. The ramming will give a firm, solid body to the sand. The point of danger in pouring basins is at the bottom *n*, Fig. 37. Here

the force of the dropping metal has such a cutting effect that in the case of large basins, it is advisable to place a core at *i*; in some cases bricks may be used instead; or again, green sand may be made to take the place of the core or bricks, by closely nailing the bottom where the iron will drop from the ladle, the heads of the nails being left even with the surface of the sand. It will be noticed that a well is formed around the core *i*, so that immediately after starting to pour, a body of metal will be formed into which the iron drops, and thus save the bottom of the basin *n* from receiving the full force of the dropping metal. In some cases the well at *n* can be made so deep that there will be no necessity for cores or bricks. However, it is well to secure this part of a basin as much as possible, for a sudden jerk of the ladle at the start (which often occurs) might prove very serious and result in the loss of the casting. There should never be less than 4 inches of good tempered sand between the bottom of the basin at *n* and the floor, or other bottom. In the case of very large basins, it is wise to have a cinder bed under them, as shown at *C*, Fig. 37.

If wooden basin boxes are used, it is well to have their fronts nailed as seen at *o*, Fig. 37 (*b*), as the wash of the metal striking the front of the basin has been known to cut away the sand and cause a bad casting. Another point to be carefully watched in making pouring basins is to avoid having water carelessly swabbed round the edges of the gates or the bottom portion of the basin, as this may start the metal blowing—and when this has once commenced, it is hard to tell when it will stop. Any boiling of the metal in the basin will create more or less scum or dirt that must follow the metal through the gates into the casting.

CLAMPING AND WEIGHTING THE MOLD.

LIFTING PRESSURE OF MOLTEN METAL.

38. When the molds have been closed, it is necessary either to **clamp** or **weight down** the copes, to resist the **lifting force** of the metal. This is readily understood

when we consider that a liquid will support a body having a smaller specific gravity than itself. Sand is lighter than iron, and for this reason it will float on the surface of that metal, unless it is held down. The actual power required to hold rammed sand down depends on the height of the column of molten metal (that is, the **head** pressure) and the weight of the core or cope that is liable to be floated by the metal; the cope or core, like a ship floating on water, will sink until it has displaced liquid iron equal to its own weight, when it will float. To make this subject as plain as possible, we will suppose that *A* in Fig. 42 is a tank instead of a mold, and has been filled with water to its top, as in view (*a*). If the block of wood *B* is placed in this tank, as shown in Fig. 42 (*b*), the water will run over its sides until the block comes to rest. If the water that ran over the sides were collected and weighed, it would be found to equal the weight of the block *B*. In other words, this block, in coming to rest, sank to such a depth as displaced a body of

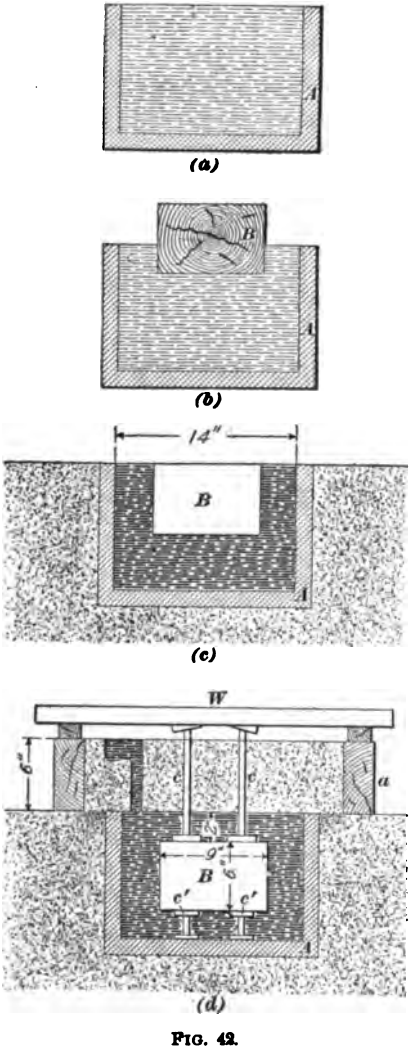


FIG. 42.

water equal to its own weight. If we desired to sink this block *B* to the level of the top of the tank, as in (*c*), sufficient weight would be required on the block to equal the additional weight of the water that would be displaced by the block sinking to the depth shown. Carrying this illustration still further, it might be desired to submerge the block, as in Fig. 42 (*d*). To do this, but very little additional weight would be required, because as soon as the block was just covered, the weight of the water above it would be practically the same as the extra amount displaced below the block. This experiment illustrates the principle involved in weighting down cores or copes, the principle being the same both for water and for liquid metal. The only difference between the two is that if the block *B* were a core submerged in liquid iron, more weight would be required to hold it down, because iron has a greater specific gravity (or is heavier) than water. A cubic foot of pure water at a temperature of 60° F. weighs about 62½ pounds, and a cubic foot of ordinary gray cast iron about 450 pounds.

WEIGHT REQUIRED TO HOLD DOWN THE CORE.

39. Submerged Cores. — Suppose the liquid to be molten iron instead of water and that the cope *a* is placed on top of the mold; find the weight *W* that would, by means of chaplets *c*, keep the core *B* from rising. The weight is computed in the following manner: assuming the core to be 24 inches long, 9 inches wide, and 6 inches deep (and its ends to be free), its volume is $24 \times 9 \times 6 = 1{,}296$ cubic inches. A cubic inch of cast iron weighs about .26 of a pound; hence the weight of the iron displaced by the core is $1{,}296 \times .26 = 336.96$ pounds. The weight of the core itself is $1{,}296 \times .06 = 77.76$ pounds, .06 being the weight of a cubic inch of rammed sand. The buoyancy of the core is, therefore, the difference of these two amounts, or 259.2 pounds, which is the weight required to hold the core from rising.

If the core were supported by prints instead of being free

at its end, its additional length and the sand over the prints required to stop them up would still have to be deducted from the 259.2 pounds; but as the core in the present case is supposed to be held up by chaplets *c*, we have here only considered the length that is *submerged*. Having found the weight necessary to hold down the core, the next step is to find the weight of the cope.

WEIGHT REQUIRED TO HOLD DOWN THE COPE.

40. Assuming the cope to measure 34 inches × 24 inches × 6 inches, its volume is 4,896 cubic inches, which multiplied by .06 gives 293.76 pounds as the weight of the cope. This is for wooden copes and is accurate enough; if it were iron, we should have to find the weight of the sides and bars separately and then that of the sand and add them together.

Having now found the weight required to hold down the submerged core, and also the weight of the cope, the additional weight necessary to hold down the cope in connection with the core must now be computed. To do this, first find the area of the cope's casting surface; this is 24 inches × 14 inches = 336 square inches. This area is multiplied by 6, the height in inches, of the head or gate, giving 336 square inches × 6 = 2,016 cubic inches. This result is multiplied by .26, which gives 2,016 × .26 = 524.16 pounds, the fluid pressure tending to force up the cope. From this weight deducting the weight of the cope gives 230.40 pounds as the weight necessary to hold down the cope alone. Adding to this the weight necessary to hold down the core, we have 230.40 + 259.20 = 489.60 pounds, the total weight to be placed on the cope in Fig. 42 (*d*).

41. Cores Partially Submerged.—There are cases where the cores are only partially submerged, their upper surfaces being in contact with the cope, as in Fig. 42 (*c*). In calculating the **static** pressure on such a partly submerged core, we have to compute the area of the lower surface of the core and also the area of that portion of the cope that has metal underneath it. Each of these is then

multiplied by the distance to the top of the highest point to which the metal may rise in pouring the mold.

In the case of a core submerged as in view (*c*) and intended to be covered with a cope, as in view (*d*), the computation is as follows: The lower surface of the core has an area of $24 \times 9 = 216$ square inches. Multiplying this by 12, the height in inches from the bottom of the core to the top of the pouring basin, we have 2,592 cubic inches; which multiplied by .26 equals 673.92 pounds, which is the upward pressure on the core. From (*c*) we find that the width of the cope having metal in contact with it is 14 inches — 9 inches = 5 inches; the portion of the cope surface in contact with the metal is, therefore, $24 \times 5 = 120$ square inches, which multiplied by 6, the height of the cope, equals 720 cubic inches, and this multiplied by .26 gives 187.2 pounds as the upward pressure on the cope. This added to 673.92 pounds gives 861.12 pounds as the total upward pressure. Deducting from this the weight of the core and cope leaves 861.12 — 371.52 or 489.6 pounds as the weight to be placed on the cope.

METHODS OF COMPUTING WEIGHTS.

42. Chart Method. — The weight required to hold down the cope and core may also be ascertained by the method shown in Fig. 43. Here we merely draw an outline

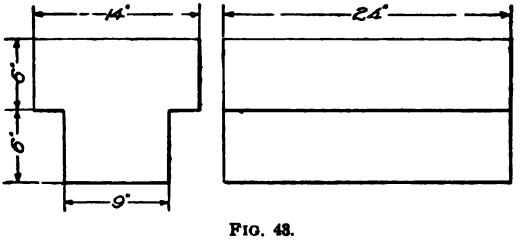


FIG. 43.

or chart of the form and sizes of the lifting surfaces, together with the height of the fluid head. This done, we compute the cubical contents of the form thus obtained and multiply it by the decimal .26. The volume of such a block as

that in Fig. 43 is $24 \times (14 \times 6 + 9 \times 6) = 3{,}312$ cubic inches, which multiplied by .26 gives a weight of 861.12 pounds. Deducting 371.52 pounds (the weight of the core and cope) we have 489.6 pounds as the weight to place on the cope, the same result as by the former method. This method of drawing a chart block of the lifting surfaces and calculating therefrom the weight to put on the cope is a very convenient one and is the one that is adopted when computations are made from drawings.

43. General Rules.—To find the weight necessary to hold down submerged cores, etc., first compute the cubical contents of the space occupied by the core and multiply it by .26; then deduct from this the weight of the core. In other words, the lifting or static pressure on a submerged core is the number of pounds of iron it displaces minus the weight of the core.

To find the weight in pounds required to hold down a cope: multiply the lifting surface of the cope by the height of the head above this surface and the product by .26.

Where one wishes to compute the weight approximately, let him imagine a weight having a face like the lifting surface, and its sides extended up to the pouring gate, according to the scheme shown in Fig. 43.

To find the static pressure on the sides of the mold: multiply the height of the sides, measured from the top of the pouring gate to the center of gravity of the casting, by the decimal .26, and the result will be the pressure in pounds per square inch.

To find the static pressure on the bottom of a mold: multiply the bottom area covered with metal by the vertical height to the top of the pouring gate and by the decimal .26, which gives the pressure in pounds.

EXTRA WEIGHT REQUIRED ON COPE.

44. While it is true that the foregoing rules for weighting down copes, etc. will give just the weights required under the simplest conditions, there are other conditions

affecting the results that must be considered and that will often demand more weight than that given by the rules. This is due to the fact that there is a moment when the metal comes up suddenly against the lifting surface, in which a sudden pressure is exerted that is greater than that of the static head, the latter being merely the steady pressure that will be exerted by the liquid when at rest. When pouring a mold, it generally takes from 10 to 50 seconds (sometimes more) to fill it with metal, whereas when the mold itself is filled, the pouring gate may fill in less than a second, thereby obtaining a head pressure in a moment's time that, owing to the suddenness of its creation, may in some cases be so great as to call for one-fourth to one-third more weight than the static-head pressure obtained by the rules just given. The higher the top of the pouring gate is above the cope's lifting surface, the greater will be this extra pressure.

Then again, some molds will be poured with more than one ladle, and the more ladles used, the greater the pressure; this is owing to the increased pressure that metal

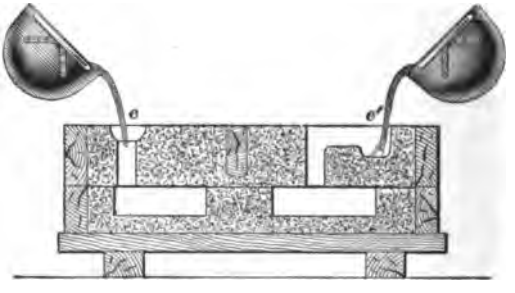


FIG. 44.

flowing from the ladle directly into a gate, as at *e*, Fig. 44, can give. This increased pressure may be equivalent to that due to a head of one-fourth to one-third the height of the ladle's lips from the top of the gate. If the pattern is gated and poured as shown at *e'*, less weight will be required to hold down the cope. There are other conditions that might be discussed, but enough has been said to indicate the variety that exists.

45. In addition to the weight rendered necessary by the head pressure, extra weight is required to allow for the **momentum lift** caused by the sudden stopping of the inflowing iron at the moment the mold is filled. The amount of this depends, briefly, on the character of the pouring system, the speed of pouring, the number of ladles, and the square inches of lifting area that the metal will suddenly rise up against, as well as the height of the pouring gate or flow-off risers above the face of the cope's lifting surface. Enough has been said to demonstrate the wisdom, and often the necessity, of placing more weight on a cope than is called for by the head pressure, and the molder must exercise good judgment in weighting down his copes.

DULL IRON AFFECTS THE LIFTING PRESSURE.

46. The lifting force of the molten metal depends in a measure on whether it is **hot** or **dull.** If the metal is dull, in most cases it will exert less pressure than if it were hotter and therefore more fluid. On the other hand the duller the iron is, the more apt it is, in molds having risers or flow-off gates, to have its pressure approach that due to the pouring basin's height, which is generally higher than that of the top of the risers or of the flow-off gates. Often the metal will "freeze" at the entrance to the risers, or it may come up the risers so sluggishly as to retard the flow of metal out of them and so cause the head pressure to approach that due to the height of the pouring basin. In the case of thin castings, if the metal is dull enough to freeze in the risers, it is not very apt to exert a great lifting pressure upon the mold. If, with thick castings, the risers or flow-off gates should freeze up or flow sluggishly, there will be exerted a lifting pressure due to the full height of the pouring basin's head.

COMPUTING THE STATIC, OR HEAD, PRESSURE.

47. Some molders compute the **head pressure** on the cope by taking the height from the top of the riser or flow-off gate, the top of which is often located 4 to 6 inches below

the level of the top of the pouring basins or gates. This is rarely a safe practice, as risers or flow-off gates may solidify or be blocked up so that the metal cannot flow freely through them. If it were always possible to count on having hot iron and enough room in the risers or flow-off gates to carry off the metal as fast as it could be poured into the mold, the height of risers would then, as a general thing, determine the pressure. Nevertheless, the safe plan is to figure from the highest point it is possible for the metal to reach in the pouring gates or risers, and then allow extra weight on the cope.

WEIGHTS FOR HOLDING DOWN COPES.

48. In weighting down molds, many founders use pig iron piled in separate pigs on the cope, or else place the pigs in stout wrought-iron rings, to be hoisted into position by a crane. Others, improving on this, cast bars ranging from 1,000 to 2,000 pounds in weight and from 3 to 6 feet in length, with hooks cast in them for convenience in handling with a crane. Other foundries preserve bad castings or take lumps of heavy scrap iron for flask weights, and handle them in the best way they can. When flask weights are required, it will be found to pay in the end to have them as handy in form and size as is procurable. This refers to weights for medium and large castings. Light-work shops

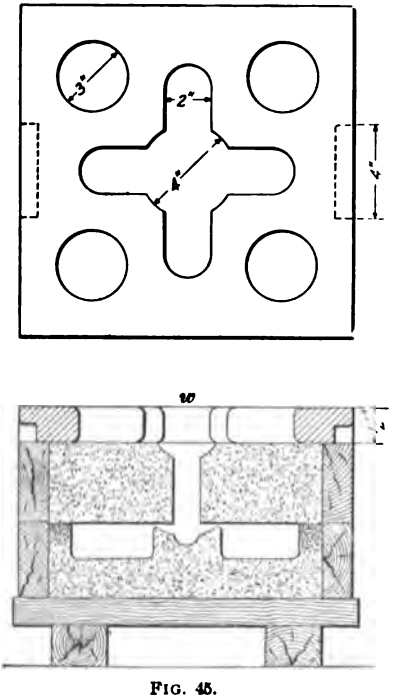


FIG. 45.

require weights for snap flasks, etc. These are generally made about 1½ inches thick and of a size to cover the entire surface of the cope, if they are not burdensome for one man to handle. These weights generally have holes in their centers and outer corners for pouring through, as shown in Fig. 45, which shows a section of a weight and snap-flask mold. The under surface of these weights should be as smooth and true as they can be cast. It is rare that a snap flask requires more than one such weight as shown at *w* upon it.

CLAMPS FOR FLASK.

49. Types and Their Use. — Shops that do much "roll-over" work should have a number of **clamps,** according to their several needs. These clamps are made both of cast and of wrought iron and should be made as handy in size and form as conditions will permit. Clamps of the forms generally used in rolling over nowels and in holding flasks together when a mold is being poured are shown in

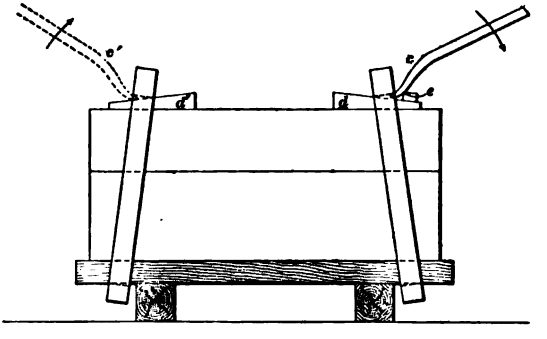


FIG. 46.

Figs. 46 to 48. Many patents have been taken out for improvements in clamps, the chief features being that their length can be changed or they can be used without wedges.

In **clamping** a flask preparatory to casting, it is not safe to drive in wedges with a hammer, as this may jar the cope and cause the sand to drop. As a rule, flasks should be

clamped by means of a "clamping iron," as at *c*, *c'*, Fig. 46. The clamping irons are made with wedge-shaped points, so as to enter the small openings between the cope and clamp and to give good leverage in either direction, as shown by the arrows. These clamping irons are, as a rule, made of old files, the points of which are turned up and sharpened.

In Fig. 47 are shown a wrought-iron clamp (*a*) and a cast-iron clamp (*b*), such as are commonly used for clamping **flanged flasks**, as shown in Fig. 48. Such flasks are generally used for dry-sand molding. Cast-iron clamps are usually tapered on the inside to permit of their being molded, the taper being shown, somewhat exaggerated, at *t*, Fig. 47 (*b*). In placing clamps on the flanges, they should be set so that the wedge will enter them at their largest side, as at *c*, Fig. 48, which shows

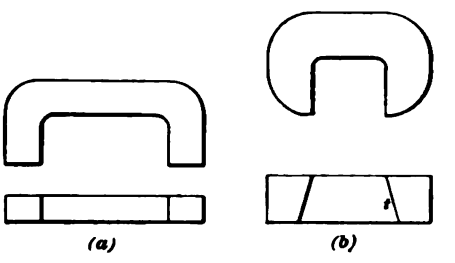


FIG. 47.

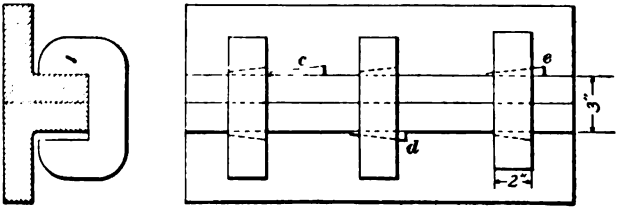


FIG. 48.

the wedge about to enter the space between the clamp and the flange of the iron flask; when driven, it should appear as at *d*.

One will often find molders trying to clamp flasks by driving wedges at the top of the clamps, as seen at *c*. This is wrong, for by trying to drive a wedge in at the top, the weight of the clamp must be lifted, and in doing this a constant jarring takes place, making it difficult to get the

clamp to a solid bearing. Not only is it difficult to tighten a clamp by top wedging, but it also requires much more time.

50. Strength of Clamp.—Where the work is such that the clamps have to resist heavy pressure, as in the case of casting rolls, pipes, etc. on their ends in dry sand, the **wrought-iron clamp** should be given the preference, as cast-iron clamps are not to be relied on in such work. Owing to **cast-iron clamps** breaking, castings have often been lost and men burned.

The proper thickness for clamps can be obtained by figuring the pressure on the flasks to be held together, and then deciding the distance apart that the clamps will be set along the flange of the flask. Knowing this, and allowing a stress in the clamp 15,000 pounds per square inch for good wrought iron and 5,000 pounds per square inch for good cast iron, one can form a very good idea as to the proper thickness for clamps.

FLOORS FOR HOLDING DOWN COPES.

51. Many foundries handling a standard class of work that can be bedded in have a large part of their floor area dug to a depth of from 3 to 6 feet, according to their requirements, and then place iron beams or binders in the bottom of the pit about 3 feet apart. A plank flooring is formed over the top of these binders; from the ends of the binders wrought-iron straps or bolts are run up to the level of the floor. This pit is then solidly rammed with sand to the level of the floor, after which the holes are dug out for molding the patterns. The molds are made after the usual manner, and binders are placed across the top of the cope directly over those in the bottom of the pit; after which, bolts are extended from the top binders to connect with those extending from the bottom ones, and the cope is bolted down in such a manner that the bolts will have to be broken before the cope can be raised by any pressure that might come on it. The practice of using these bolting-down floors instead of weights is a good one.

CHAPLETS.

TYPES IN GENERAL USE.

52. Chaplets are used to support or hold down cores that, owing to their shape, are not self-supporting when placed in the mold. There is a large variety of such chaplets in use; those shown in Fig. 49 are called **single-headed chaplets,** those in Fig. 50 are called **double-headed chaplets.** Fig. 51 (*a*) is a *spring chaplet;* (*b*) is

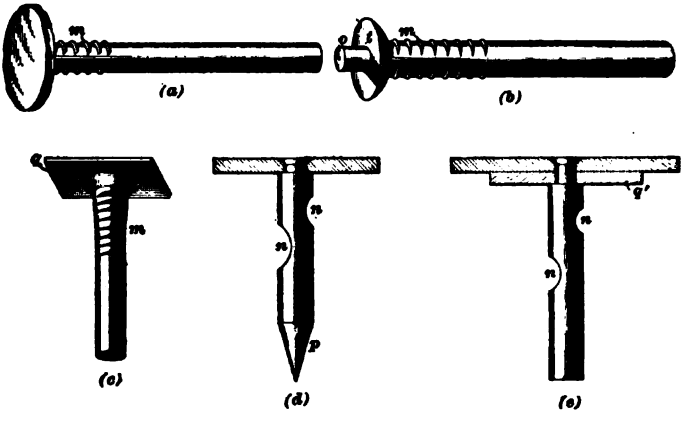


FIG. 49.

a combination of *chaplet and stand,* a scheme often used to save labor and time in setting chaplets. The stand can be set in the nowel under the pattern when it is being rammed up, and then when finishing the mold, the chaplet is set in, as shown; see *a*, Fig. 52. Often iron cross-bars in both nowel and cope have knobs cast on them into which holes are drilled to permit chaplets being inserted after the manner shown in Fig. 51 (*b*). The chaplet (*a*) in the same illustration is made of a piece of steel or iron that can be pressed together and then allowed to spring back to the desired form. There are places where these chaplets are of special value.

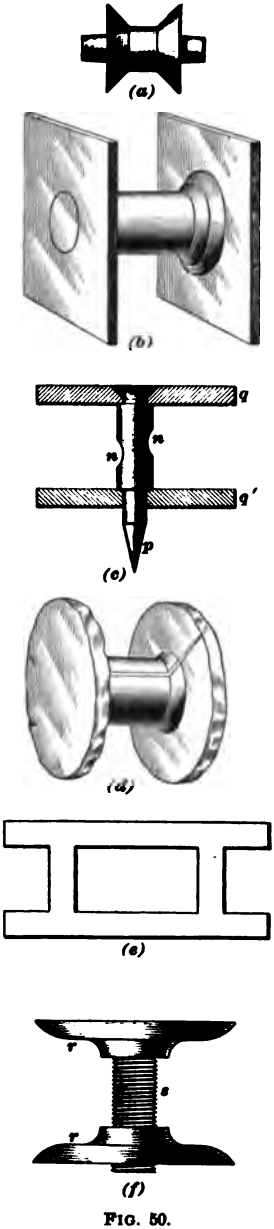


FIG. 50.

In Fig. 49, chaplet (*a*) is made of round iron, cut to any desired length and having a solid head, as seen; (*b*) is a *chaplet stem*, on which, at the head *o*, any size of plate may be riveted. Often larger heads than can be forged upon a chaplet, as in (*a*), are required, and such stems as (*b*) permit their being placed on; (*c*) shows a stem with such a head *q* riveted on. There are times when the pressure will be so heavy on a chaplet, or when the cores may require a large bearing surface, that the plate *q*, chaplet (*c*), is better if reinforced by a *back plate*, as at *q'*, chaplet (*e*). Chaplet (*d*) illustrates how a *sharp point p* is sometimes necessary to permit its being driven

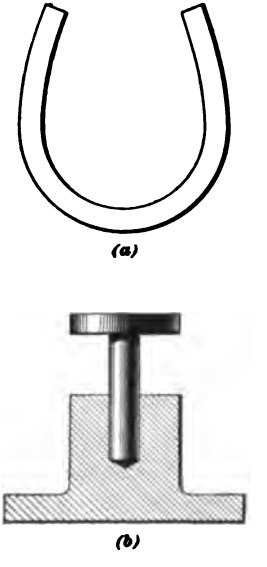


FIG. 51.

into bottom boards, wooden blocks, etc. underneath the surface of the mold, as seen at *b*, Fig. 52. In driving such chaplets, it is only necessary to go to a depth of ½ inch to ¾ inch, as beyond this depth the pounding is liable to drive down the block or to jar the board and loosen parts of the mold. Turning now to Fig. 50, (*a*) is a *double-headed chaplet* stem, of required length, so that plates of any size may be riveted to them, as shown at (*b*). Double-headed chaplets often have to be fastened to the surface of the mold or core, so that any jarring of either may not move them; this is done by making the chaplet with a sharp stem *p*, as seen in (*c*). These sharp stems are driven into the face of the mold; they seldom require to be more than ¾ inch long. An inspection of chaplet (*c*) will show that the heads *q* and *q'* are placed on after the stem has been made and that the top head *q* is riveted on. (*d*) is a double-headed forged chaplet, while (*e*) is a cast-iron one. Cast-iron chaplets can often be used, but care must be exercised not to place them where they will be struck by the stream of metal from the pouring gates, as they melt more readily than wrought iron; in fact, this is a point that must be guarded against in the use of all chaplets, as many castings have been lost because molders have thoughtlessly set chaplets in front of gates that will have large bodies of metal flowing through them; or, again, the quantity of the iron may be small, but yet be so hot as to easily melt the chaplets.

There are several firms in this country making a specialty of manufacturing chaplets, especially those shown at (*a*), (*b*), (*c*), Fig. 49, and (*a*), (*b*), and (*d*), Fig. 50, and they can be purchased at a much less cost than any person, requiring only a few, can make them.

Fig. 50 (*f*) shows an *adjustable chaplet*, a very convenient appliance where odd lengths are needed. It consists of a stud or stem *s*, made by threading stock of the required size in the screw machine and cutting them to the most convenient length. Ordinary cast-iron washers *r* are drilled and tapped to suit the threaded stem *s*. An

adjustment ½ inch or less may be made with the washers *r*, while a variety of lengths of stems permits the making up of any size. The stem here shown is ⅝ inch in diameter and the washers 2½ inches.

PRECAUTIONS IN USING CHAPLETS.

53. Chaplets are generally "necessary evils," since wherever they are placed, they are very apt to weaken the casting at that point more or less. They may do this in three ways: *First*, by breaking the uniformity of the metal of the casting by the introduction of some other substance at the point occupied by the chaplet; *second*, by working loose and leaving holes in the castings, generally caused by blowholes being around them; *third*, by causing porous or unsound metal to form around them. The first of these evils cannot be avoided; but by good design and care in the making and use of the chaplets, the second and third evils can be greatly decreased, and in many cases almost wholly avoided. In regard to the second evil, chaplets should be nicked or have depressions made in them, as at *n*, Fig. 49 (*d*), or else have burrs on them, as seen at *m*, Fig. 49 (*a*), (*b*), and (*c*).

Some molders, in making the stem, avoid the heavy shoulder *t* shown in Fig. 49 (*b*) and make the stem sufficiently large to give a good bearing to the head *q* in (*c*), as shown in Fig. 49 (*d*) and (*e*). Some persons cut a thread on the part of the stem that is cast in the metal, even in the case of chaplets that have fixed heads. This scheme is used also in making double-headers, as in Fig. 50 (*b*), and in such cases a thread will be cut the whole length of the stem and the heads screwed on, as in Fig. 50 (*f*). The screw stem has an advantage in another way, as the cutting of the thread removes all scale or rust from the surface of the stem, and this is very important, as any rust on the chaplets may do great injury.

RUST ON CHAPLETS.

54. There is always more or less **rust** or **scale** adhering to the surface of both old and new chaplets. As much as possible of this should be removed from the parts that are cast in the metal. When molten metal comes in contact with rust, a gas is created. It is calculated that 60 grains of dry rust will make 31 grains of carbonic-oxide gas, which at 2,800° F. (the temperature of molten iron) and the pressure of 1 atmosphere will occupy about 600 cubic inches of space. It does not require a very large piece of iron to give 60 grains of rust. The space that the gas occupies depends on the pressure; and the amount of harm it can do depends on the rapidity with which the metal solidifies and thus prevents the gas escaping. Blowholes are rarely found around the chaplets in the lower part of a casting; it is in the upper part where there is very little pressure during the pouring that they occur. The part of a mold where the greatest pressure exists is usually the first to be filled, and the iron is also hotter and cleaner there than at the top of the mold. If, for any reason, the chaplets at the bottom should cause the iron to boil or blow, the gas will generally escape upwards through the metal and out at the top of the cope sand or out of the flow-off gates.

Chaplets may be free from rust when placed in the mold, but if kept there for two or three days before the mold is cast, they are very apt to become rusty, especially if the mold is a green-sand one. There are varnishes that can be used to prevent their rusting, and these will be dealt with farther on.

MOISTURE ON CHAPLETS.

55. A piece of polished iron, if exposed to **moist air** or otherwise moistened, soon becomes rusty. This is due to the affinity that iron has for oxygen. Under certain conditions, polished iron can be kept free from rust by keeping it in a dry atmosphere. Take polished iron from a cold room into a warm, moist one and it will not be long before rust will

be formed upon it—an effect caused by the cold iron condensing upon its surface whatever moisture there may be in the air immediately surrounding it. The more rust there is on iron, the more moisture it will collect; and on chaplets, this moisture can do greater injury than rust. To test this, take a rusty rod and heat it sufficiently to dry all its moisture, after which place it quickly into a ladle of molten iron. The metal will be found to bubble around the rod, more or less, but it will not fly out of the ladle, as it would if there were moisture on the rod. The steam that the moisture on chaplets creates may cause a great amount of bubbling or blowing, as can be seen by quickly immersing a damp rod in a ladle of iron.

The best thing that can be done to prevent chaplets from becoming rusty and collecting moisture is to **tin** that portion liable to be encased by the metal. Coating the iron body with tin not only prevents the oxygen or moisture from attacking the iron, but it has an affinity for iron that makes the iron more fluid when in a molten state, and this greatly aids the release of any gases that might be created around the chaplets.

Where chaplets are not **tinned,** many molders cover their exposed parts with a coating of red lead mixed with turpentine. Asphaltum, coal tar, and chalk are often used as a coating. Where there is much moisture, these materials may collect sufficient dampness to cause injury, but not to such an extent as rusty chaplets.

SETTING AND WEDGING CHAPLETS.

56. There are few things more annoying than to see castings lost by thoughtlessness or ignorance in **setting and wedging** chaplets. Chaplets are generally set into a cope by first passing a $\frac{1}{8}$-inch rod or vent wire up or down through the cope at the spot where it is desired to place the chaplet. If the chaplet is larger than $\frac{1}{4}$ inch, then a $\frac{1}{4}$-inch vent wire or rod is passed through the hole made

by the $\frac{1}{2}$-inch rod, and so on, increasing the size of the rods according to the size of the chaplet stem, the idea being to gradually enlarge the hole for admission of the stem without applying much pressure. After the stem has been pressed through the body of the cope, it should then be pulled out and the hole reamed out at the face of the mold, as seen at *c*, Fig. 52. Many molders having failed to do this when pressing down the chaplet to a good bearing on the core, or

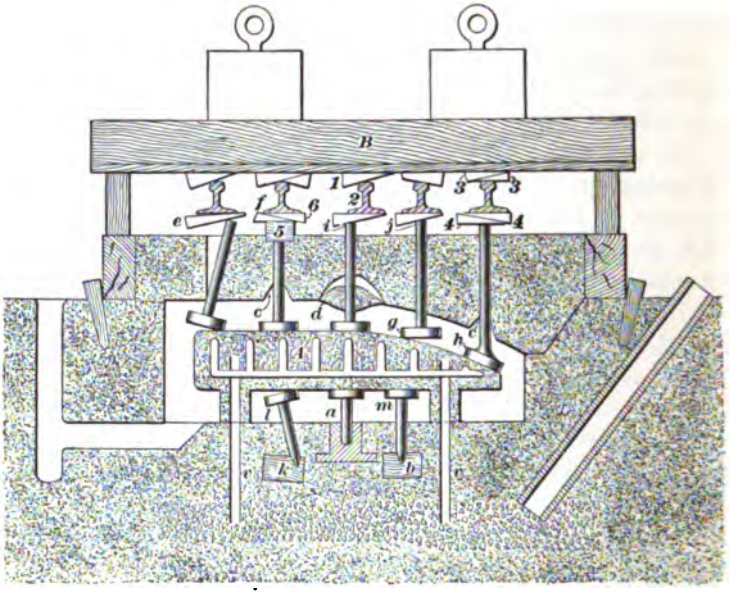


FIG. 52

in wedging it down to place, have caused the face of the mold around the bottom of the stem to be pulled down, as at *d*, thus resulting in the loss of the casting.

After the chaplets have been set and the cope closed, some molders drive in wedges with a hammer to fasten the chaplets, as at *e*. This results in displacing the chaplet, as shown. The chaplet should be placed solidly upon the core *A* and then wedged down as shown at *f*. Then again, some molders in fastening down cores having slanting surfaces use

chaplets having the head at right angles with the stem, as at *g*. Where the surface of the core is slanting, the heads of the chaplets should be set on the stem at the same angle as that of the core; care should be taken that the slant of the head and core agrees, so that they may come solidly together when the cope is closed, as at *h*.

BLOCKING ON TOP OF CHAPLETS.

57. Very often the chaplet stems will require some **blocking** on top of them, as at *5*, Fig. 52, before wedges can be used. Where this is necessary, care must be exercised in making sure that the blocking is over the center of the stem and also that there is sufficient space to use the wedges *6*. While it is often necessary to use blocking, there are many cases where its use can be avoided if judgment is used in placing the rails, in weighting down the binder *B*, and in getting the chaplet stems the right length. Molders often leave the chaplet stems sticking up from 3 to 6 inches above the top of the cope; and sometimes they leave them from 1 to 3 inches below this same level.

Lack of system and judgment in some molders will cause them to use from 100 to 200 pounds of small pieces of blocking to fasten down a half dozen chaplets, where other men will do the same work without a pound of blocking. The fewer pieces of blocking that are placed between the weighting-down binders or rails and the wedges necessary to fasten the chaplets, the better it is for the safety of the mold. In many cases, with forethought and judgment the chaplets can be cut to such a length and the binders can be so arranged as to avoid the necessity of using any blockings between the top of the chaplet stems and the bottom of the weighting-down binders. Where this is possible it should be done; and in allowing space for wedges between the top of the chaplet stems and the bottom of binders, it should range from $\frac{1}{8}$ inch to $\frac{3}{4}$ inch in depth. Before wedging the chaplets, the weights necessary to hold down the cope should

be placed upon it, as all the binders, etc. will **spring** more or less when weighted; and if the weights are placed after the chaplets are wedged, this springing may drive the chaplet heads into the face of the cores and cause damage. Just before pouring a mold having chaplets, it is good practice to go over it to test the wedges, as it is not uncommon for them to work loose in a little time after they have been tightened.

PLACING CHAPLETS IN BOTTOM OF MOLD.

58. It is as important to have chaplets rightly set in the bottom as in the top part of molds. A great number of the chaplets used in the bottom of molds are driven into the bottom boards or into wooden blocks. Where wooden blocks are used to support cores of any great weight, they are best made of hard wood, set with the grain up. In driving the points, as at *b* and *k*, Fig. 52, the molder must use his judgment as regards the proper distance, taking into consideration the size of the chaplet stem, the weight of the core, and the nature of the block.

Some molders lose castings by the manner in which they set bottom chaplets. The block *k*, Fig. 52, is apt to split for two reasons: *first*, because the chaplet has been driven in too far, and, *second*, because the point is near the end of the block. The block *b* shows the proper practice in these respects. Where points are driven as at *k*, castings are very liable to be lost through the settling of the chaplet into the block. Even if the core's own weight does not do it, the wedging down of the top chaplets when the cope is closed will probably do so. A fine wire should be pressed through the sand to find the end of each block, so that when the chaplets are being driven one may know how near they are to the center of each block. The head of the chaplet *l* is shown in such a position that it makes an angle with the core and having but one edge touching it. It is as important to have bottom chaplets properly set as top ones, for it can readily be seen that if a core does not

set solidly on the chaplet, as at *m*, much risk is taken. At *a* is shown a chaplet placed in a stand, the appliance illustrated in Fig. 51 (*b*). These stands are very good for some classes of castings, as, for example, in cases where it does not matter if the face of the casting is chilled a little at and around the spot of the chaplet connection. By placing sand in the bottom of the hole admitting the chaplet's stem, any variation in the thickness of the metal can be arranged for in setting the chaplet.

WEDGES FOR SETTING CHAPLETS.

59. In making wedges either of wood or iron, it is best to make them of as easy a **taper** as practicable. The greater the taper is, the more difficult the wedges are to

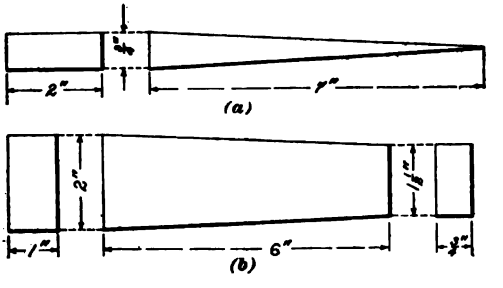


FIG. 53.

fasten and the more liable to work backwards from the bearing when tightened. The wedges shown in Fig. 53 represent what is considered good practice. They can be fastened without much danger of their being loosened by jars when other wedges are being driven. Wedge (*b*) is generally used for resisting great strains and to partly take the place of blocking; it can be made of any size to suit the conditions of the work. The quick-tapering wedge (*a*) is the one most commonly used, and the dimensions given can be applied to either cast-iron or wrought-iron wedges.

"DRAWING DOWN" OF THE COPE.

60. The phrase **drawing down of the cope** is applied to copes whose surface sand drops down upon the metal as the mold fills up. This is caused by the heat of the metal drying the surface of the cope; if the sand in the latter is not of such a nature as to bake solidly to the depth penetrated by the heat, and it does not hang well when one part is drier than another, then the sand will often drop upon the metal in small quantities and cause lumps and dirt holes in the upper surface of the casting. Not only does this contingency depend on the nature of the sand, but also on whether the mold is kept air-tight or not. With strong sand in the cope, some molds may be cast with their feeders, risers, etc. all open, and no injury will occur to the casting; while, with other grades of sand, if this were done, the whole surface would be drawn down. It is chiefly with such castings as thick plates or heavy blocks, where the cope surface is exposed to the direct heat of the metal from the moment it enters the mold until it comes against the upper surface, that difficulty is experienced by drawing down. Any part of the cope's surface that is exposed for $\frac{1}{2}$ minute to the direct heat of rising metal should have a strong grade of sand for the first $1\frac{1}{2}$ inches of the surface sand and in addition should be closely gaggered, with the sand not more than $\frac{3}{8}$ inch thick under the gaggers. In ramming the first course of sand in such copes, it should be evenly and firmly done; and the weaker the sand, the harder should be the ramming.

When the sand is weak, it may be strengthened by mixing flour with it or by wetting it with clay wash, and sprinkling it well with molasses water or beer after the surface of the mold is finished; in fact, it is well to do this with even strong grades of sand, where they are expected to be exposed to the direct heat of the metal for more than $\frac{1}{2}$ minute. Use 1 part of flour to from 15 to 25 parts of sand according to the strength of the latter; the weaker the sand, the more flour is necessary. In some cases where the

copes are to be exposed to intense heat, as in very thick plates or anvil blocks, it is often advisable to nail all the surface between the gaggers, keeping the nail heads either even with the face of the cope and covered with blackening or else ¼ inch away from the surface and covered with sand and blackening. In venting green-sand copes that are liable to be drawn down, the vents should not be carried any closer than within 1 inch to 1½ inches of the surface, since, if they are carried close to the surface, they will permit the escape of gases and relieve the pressure against the face of the cope.

Not only does drawing down occur in green-sand copes, but also in dry-sand and loam copes or covers. Both weak and strong sands are used in these latter molds, as well as in the green-sand molds, and where there are heavy bodies of molten metal directly under the copes, dry-sand and loam mixtures require to be strong also, or else drawing down will occur, as in green-sand work.

PRESSURE OF GASES IN MOLDS.

GENERAL REMARKS.

61. There is a great deal of difference in the practice of molders in leaving the feeders and risers open or closed while casting. It is seldom injurious to any large mold to cast it with all its risers and feeders closed perfectly air-tight. Molds that are liable to have the copes "drawn down," or in which the rushing of hot gases upwards through the risers will have a tendency to draw the gases from the vents in the bottom, should be cast air-tight as far as possible. The rush of hot air and gases through open risers has a tendency to divert the gases generated in the bottom of the mold from going downwards, causing them to pass up through the under surface of molds and producing scabs on the bottom of the casting. This rush also relieves

the mold of the internal air pressure that exists when the mold can be kept air-tight; and this pressure is often sufficient to prevent weak grades of sand from being drawn down from the surface of the cope.

Air is like all other gases in that it expands with an increase of temperature. At a temperature of 500° F., air has about double the bulk that it has when at 0° F. The temperature of the air and gases in a mold is perhaps about one-half that of the rising metal; it may safely be taken as at least one-third. This means that the air and gases in a mold will have a temperature of 600° to 1,000°, and that the gases in a mold having open risers would be increased in volume to two or three times as great as before the liquid metal commenced filling the mold. In an air-tight mold this would cause the pressure of the air to increase with its temperature. In other words, the air in a mold before casting was begun would have the pressure of the atmosphere, which is about 14¾ pounds per square inch, but by increasing the temperature, the pressure of the air and gases in an air-tight mold would increase from 2 to 4 pounds per square inch over the atmospheric pressure. Such a pressure at the face of the mold is very effective in preventing the surface of the cope from drawing down, and also prevents the gases from rising upwards in the lower part of the mold where they might cause scabs, or worse still, start the mold blowing. In casting small molds the risers can often be kept open without injury; this is also true in dry-sand and loam molds that have solid faces with little cope surface exposed to the metal. Aside from these, all risers and feeders should, as a rule (especially in heavy green-sand work), be closed air-tight and weighted down so that any increase of gaseous pressure cannot lift them.

Where risers are left open in any mold, they should be sufficiently large in area to allow the expanded air and gases to escape freely, as air rushing through these passages is apt to do damage by cutting away the sand around them.

COVERING THE FEEDING HEADS AND RISERS.

62. When covering the feeders and risers, as at *n* and *o*, Fig. 54, care should be exercised, as the least opening leaves room for the air and gases to rush out, and this would continue to increase the area for escape as long as the mold was

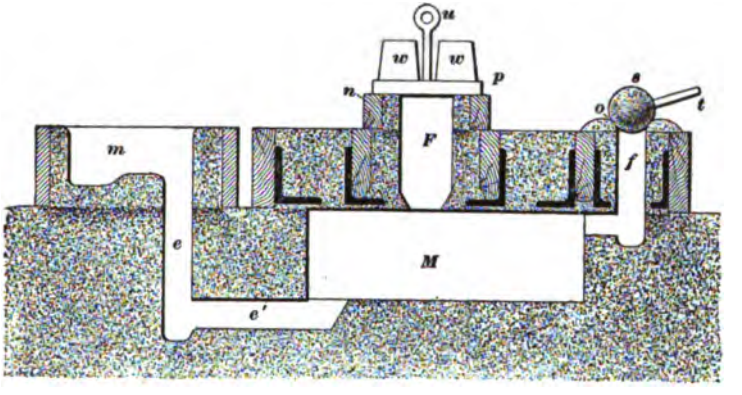


FIG. 54.

being poured. In placing covers on the feeding heads, as at *n*, Fig. 54, the covering plate *p* should have a good bearing over the top of the feeder box or projection, and to insure a tight joint, flour paste, parting sand, or dry flour is put around the opening for the covers to press upon. Flour paste is the best, and should be used for all heavy castings or work having cope covers or projections where the liberation of compressed air or gases might cause scabbing or blowing of the molds. After the feeding heads *F* are covered, they should be weighted as at *w*. The combined weight of the cover and weights placed on feeders or risers should be estimated according to the liability of the mold to have a high temperature of the air and gas inside it; this point must be left to the judgment of the molder. It is always best to have more weight on *p* than is really necessary, for an excess of weight can do no harm. Where feeders or risers are not more than 2½ inches diameter, balls of clay are often used, as shown at *s*. These balls of clay

should be of such consistency as to hang together well. In some cases it is well to stick a rod in the ball of clay, as seen at *t*, and to have handles on the cover plates, as at *u*.

BLOWHOLES.

63. In pouring a casting with very dull iron, it is sometimes advisable, where there is not too great a danger of the cope drawing down or the gases working upwards from the bottom of the mold, to leave some risers open, as too close confinement of the air and gases may cause blowholes in the thinner parts of the casting. Castings are frequently found to have what are called "shrink holes" and "blowholes." The latter is generally a hole having a smooth surface and is rarely larger than would hold a teaspoonful of water. Castings may be so full of blowholes as to look like a honeycomb.

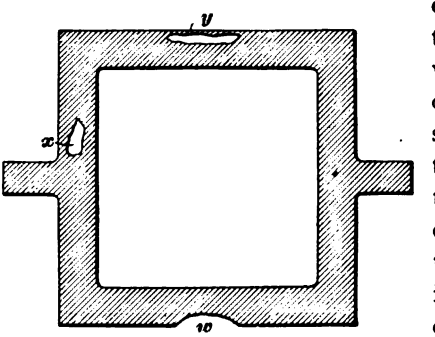


FIG. 55.

Blowholes, whether in large clusters or found singly in different parts of a casting, are caused by the gas or steam (generated from the moisture in the sand, facings, etc., that composes the mold) endeavoring to escape, but being caught by reason of the dulness of metal, which solidifies before the gas can pass out entirely. One may expect blowholes in any casting where the cores do not vent freely, or where the mold, from any reason, may cause the metal to kick or blow. Where the metal kicks or blows in a mold, the formation of blowholes may often be prevented by flowing metal through the risers. This is especially effective where the inlet gates carry the metal to the bottom of the mold,

and flow-off gates or risers are placed at the top. Where hot metal fills a mold that blows or kicks and is slow in solidifying, the gases may free themselves without much flowing of the metal through the risers.

There are two kinds of blowholes: one is found in the interior of castings, as at *x*, Fig. 55; the other is found on the exterior, as at *w* and *y*. These exterior holes are more often found in the form of indentations, as at *w*. Such a formation on the bottom of a mold or casting is caused by the heat of the metal drawing the gases to one spot—as when there are several vents leading to one main vent, or where there is a softness in the mold at that point. Or it may be that there is a hard spot in the face of the mold, and the gases, not finding relief downwards, try to pass through the metal and are caught and imprisoned by the solidifying iron.

The form of blowhole seen at *y*, Fig. 55, is generally caused by gases passing from the bottom of molds or cores upwards through the metal in an effort to escape through the cope surface; but if there is a damp or hard spot in the surface of the cope, it will chill the metal and form a thin crust through which the gases cannot escape, and being unable to go any farther they will be imprisoned and form the hole shown. Such holes as at *y* are chiefly found in thin castings, ranging from $\frac{1}{4}$ to 1 inch in thickness; in such cases the cope exerts a greater chilling effect than it can where there is a thick body of metal. Often the surface of a light casting appears solid until one passes a scraper over it, when, from the sound made, hollows may be detected; on breaking the crust, it will be found that these hollows or indentations are generally of a very smooth character, which shows that they were formed by imprisoned gases. A remedy for this is to have vents in the bottom of the molds of such character as to pass off the gases freely in that direction, and also to guard against copes having wet or hard surfaces. The drier the sand can be used and the softer it is rammed at the surface of copes covering thin castings, the better.

SHRINK HOLES.

64. A **shrink hole** differs in appearance from a blow-hole in that the former generally has a rough surface while the latter has a smooth one. The shrink hole generally looks as if a body of metal, of the same form as the hole, had been torn out, leaving a very rough open-grained fracture. It is caused by the parts that are the first to solidify shrinking and drawing metal from those that solidify last. This is due to the peculiarities in the cast iron that cause expansion at the moment of solidification, before contraction takes place, and also to the fact that thin or exterior portions solidify with a closer grain and possess higher combined carbon and a greater specific gravity than interior or heavy parts, even when poured from the same ladle of iron. The harder the iron the more noticeable will be these conditions. With very soft grades of iron little difficulty will be experienced from shrink holes, unless the castings are heavy. Where the iron is hard, either high in combined carbon or low in graphitic carbon, the shrinkage will always be great compared to that in soft iron. This is so true that, unless hard iron castings are very carefully proportioned, considerable shrinkage may be expected in the parts that are the last to solidify, unless these have been provided with feeders through which compensation for the shrinkage is made with good hot metal. This point is well shown in Figs. 56 to 59.

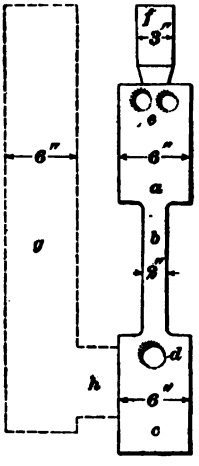


FIG. 56.

Molders are sometimes held responsible for shrink holes that it was impossible for them to avoid. For example, consider Fig. 56, which shows a section of a casting having a light body at *b* connecting two heavy ones, as at *a* and *c*. It is evident that the lighter body *b* will solidify before the heavier ones *a* and *c*. This means that such a piece, if cast in a vertical position, will probably have shrink holes at *d*.

The reason of this is that after the light section *b* has solidified, the outer portion of *c* will, in order to get iron to supply its shrinkage, draw metal from the portion that was the last to solidify, and there being no means of reaching this part with additional metal, cavities at *d* are formed. The holes *e* occur near the upper end of the casting, instead of near the light section *b*, owing to the fact that the metal commences to solidify at the bottom and then gradually works upwards until the whole body is solid. The heat in escaping from a casting radiates upwards more freely than in other directions, and, hence, the topmost bodies are kept hot the longest. The holes at *e*, in the upper end of such a casting, can be prevented by having a feeder *f* through which, after the casting is poured, additional metal may be fed to replace that taken away from the portion at *e*. The only way to prevent holes at *d* in such a vertical casting is to have a feeder leading down to *c*, as indicated by the dotted part *g*, if this is practicable; but this is seldom possible in ordinary work. It should also be borne in mind that if the feeder *g* is to be effective in preventing holes *d*, this feeder must be larger than the section *c*, so that the feeder and its inlet *h* will be the last to solidify.

Another example of a shrink hole may be seen at the upper end of the vertical casting shown in Fig. 57. Here the riser head *f*, used chiefly to receive the dirt, has an area at *a* larger than at any other portion of the section. A study of Fig. 56 should make it clear why shrink holes are formed at *a*, Fig. 57. To prevent the formation of such holes, perfect feeding is required. If the feeding is omitted, then the section at *f* should be enlarged to a thickness equal to that of the casting measured on the line *m m*; this would give us a **sinking head,** like that shown by the dotted line *n*, 4 inches thick instead of the original 2 inches. By having a sinking head 4 inches thick, it will be self-feeding, so that instead of the holes being at *a*, we shall find them higher up, at *b*. The principle involved in this scheme of self-feeding is illustrated, also, in Figs. 58 and 59. Here is shown a roll supposed to be cast on end. Some molders, to save

lathe work or labor in cutting off feeding heads from such castings, will place feeders as seen at *f*, coming down to a neck, as at *g*, and then feed the casting with churning rods and an occasional pouring of hot iron into the feeding head.

FIG. 57.

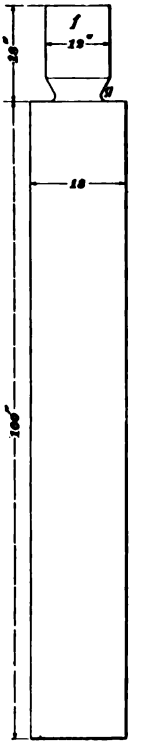


FIG. 58.

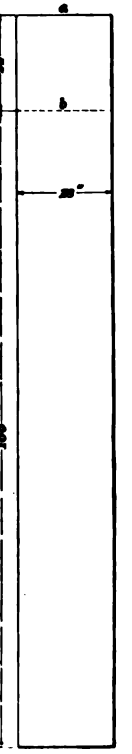


FIG. 59.

Instead of depending on care, judgment, and skill in feeding such castings, some molders avoid the neck at *g* and simply carry the casting up straight, and have it appear as in Fig. 59. After these molds are cast, the upper end is covered with blackening to prevent heat escaping, and then the extra length of the casting used for a sinking head is kept full of metal, by occasional pouring as it shrinks away. After the casting is cold, the extra length provided for a

sinking head is cut off. The length of the sinking head from *a* to *b*, in some cases, ranges from 2 to 3 feet in order to insure the body of the casting below the level of *b* being perfectly solid. A great many founders cast hydraulic cylinders, rolls, shafts, cannon, etc., on this plan, having learned from experience that this is the best way to obtain castings free from shrinkage defects.

SHRINKAGE AND CONTRACTION.

65. The actions of "shrinkage" and of "contraction" are distinct in their nature, and are separated by the act of expansion that takes place at the moment of solidification. As will have been gathered from the last few articles, **shrinkage** is that property of the metal when liquid that causes it to decrease in volume while cooling, until the moment it becomes solid. At the moment the iron becomes solid there is a slight expansion, but as it is much less than the previous shrinkage it is rarely noticeable, especially in large castings. After iron has solidified, it commences to decrease in dimensions until it reaches the temperature of the atmosphere; this is **contraction.** When discussing the practical work of founding, the ground is cleared and discussions simplified by making the above distinction. Light-work molders and founders not having to make heavy castings, in which the greatest shrinkage is displayed, are very apt to confound shrinkage with contraction. Nevertheless, they are two separate actions and should be recognized by distinctive terms.

FEEDING THE MOLD.

IMPORTANCE OF PROPER FEEDING.

66. **Feeding** can be properly done in many cases without the use of large **feeding heads**—which are often very costly to remove from the casting. Many molders think that as long as a casting has a feeder, no matter how small its

size, that is all that is necessary. The man that thoroughly understands the principle of feeding will proceed with discretion in placing such feeders as shown in Figs. 58 and 59. If he has a feeder like that in Fig. 58, he knows that great care and skill must be used in order to get a sound casting. In contrast to this, it is no uncommon thing to see a molder using a feeding head that will solidify almost as soon as the mold is poured, although the casting underneath the feeder may remain in a fluid state from 15 to 30 minutes. Such castings would be better without any feeder, as by a small feeder a molder can draw out more iron than he puts in. Whenever a feeder is used, it should be sufficiently large to permit of feeding the body of metal below it as long as the latter remains in a fluid state. Some molders can accomplish this by means of a smaller feeder than can others, although the difference in size may not be great.

Usually, the greatest difficulty in feeding is to keep the smaller sizes of feeding heads open. A head from 2 to 3 inches in diameter should be kept open from 10 to 15 minutes; and the molder should be careful not to use too large a feeding rod. Sometimes a molder will take a $\frac{3}{4}$-inch round, cold iron rod and use it in a 2-inch feeder; the result is that the cold rod chills the liquid metal the moment it is inserted, and being nearly the size of the feeder, the chilling rarely permits the removal of the rod.

FEEDING HEADS.

67. For a 2-inch feeder the diameter of the **feeding rods** should not be more than $\frac{5}{8}$ inch. For a 3-inch to 4-inch feeding head, a $\frac{1}{2}$-inch rod will work well. For 4-inch to 6-inch feeders, $\frac{5}{8}$-inch to $\frac{3}{4}$-inch rods will work nicely. In all feeding heads above 6 inches in diameter, rods from $\frac{3}{4}$ inch to 1 inch in diameter can be used. Before being inserted into a feeder, the rod should always be well heated in a ladle of hot metal, so as to prevent its chilling the metal in the feeding head; the metal in this head is

generally dull on account of its having flowed upwards from the bottom to fill the feeder. When placing a rod into a feeding head, it should pass through the head and enter the casting to a depth that will insure hot iron being fed into the part that is going to shrink. Too many molders push the feeding rod no deeper than the bottom of the feeding head; some do this through ignorance and others to get rid of a hot job quickly. In the ordinary molds, one should, on inserting the feeding rod *r*, Fig. 60, be careful to pass it down gently until it is felt to strike the bottom of the mold, and then to draw it up a few inches, as shown at *b*,

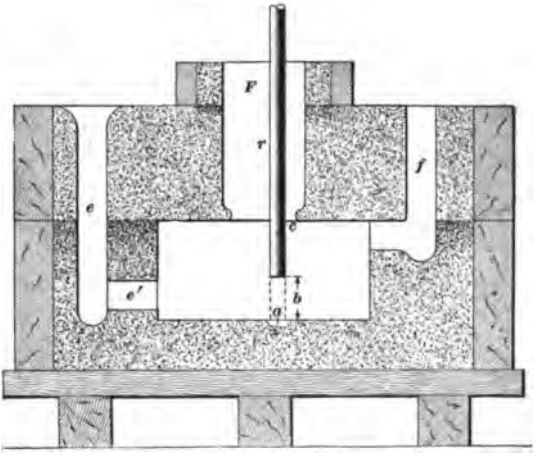


FIG. 60.

so as not to make a lump on the casting at *a*. After the feeding rod has been raised off the bottom, it should be worked up and down through a distance of 3 to 5 inches, according to the character of the mold, observing to keep it near the outer sides of the feeding head *F*, as at *c*.

HOT IRON FOR FEEDING.

68. In using feeding rods, care should be taken to have plenty of hot metal in order to keep the feeder open, so that the metal in the feeding head may be as fluid as that in the casting below the head. There is altogether too much

disregard of this important point, and one may often see molders in difficulty from the start for want of hot iron to keep the feeding heads open. Where one has hot metal when necessary, feeding should be continued until the gradual solidification of the casting from the bottom upwards has pressed the feeding rod up to the lower edge of the feeding head. This stage reached, hot metal should be poured into the feeder while the feeding rod is being gradually removed. Any one feeding in this manner will obtain a solid casting.

Fig. 61 shows a molder in the act of feeding a mold and a second person pouring hot metal out of a hand ladle

FIG. 61.

to keep the feeder open and supply the shrinkage of metal in the casting.

USE OF LARGE FEEDERS.

69. Often with feeders over 8 inches in diameter, one will not need to insert a feeding rod for quite a time after the mold has been poured, for the reason that the iron does

not commence to shrink until it is approaching the point of solidification, which is not until the metal in contact with the walls of the mold or core has cooled down considerably.

Many molders when feeding large heads like that in Fig. 58 cover the metal in the feeding head with dry blackening or charcoal dust as soon as the mold is poured, to keep the heat from escaping, and then pour in hot metal occasionally, as the feeding head settles. This may be continued in large feeders (over 12 inches diameter) from 30 to 60 minutes, or as long as it is safe to do so, this being determined by occasionally passing a hot feeding rod into the casting and observing whether any metal sticks to it when pulled out. When iron commences to stick, it is time for the molder to put in the feeding rod for constant and careful operation, or until it is driven upwards and out of the casting by the solidifying metal, as already described.

FEEDING RODS.

70. In feeding heavy castings, there should be several feeding rods on hand, a few of them smaller than the ones generally used, so that if one rod becomes badly clogged, it can be removed and a clean one used. Feeding rods may often be kept from becoming clogged by tapping them lightly with another rod held in the hand, as shown in Fig. 61. This jars off the metal that clogs the rod, and assists in keeping the feeding head open until the casting has solidified. The partially solidified iron that is jarred off the feeding rod can be worked into the casting; this takes it out of the way of the feeding and still benefits the casting by helping to cool the metal. With very large feeding heads, it is sometimes a good plan to use a small iron scoop and dip out the dull metal in the head for a depth of about 6 inches and replace it with hot metal direct from the cupola, which, after being poured, can be churned up and down with the feeding rod to open the feeding head, and so obtain a good,

clean hole to continue the feeding. To be able to keep a feeding head open until the solidifying metal drives the rod out of the casting is an operation requiring skill on the part of the molder.

SNAP FLASKS.

71. A very large number and variety of small light castings are made in what are called **snap flasks.** For

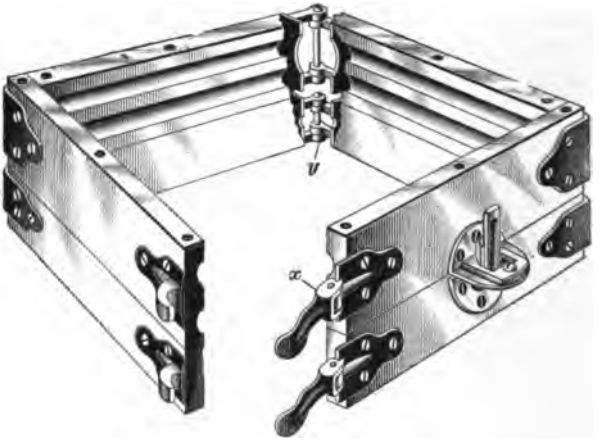


FIG. 62.

common use on the bench, these flasks range from 10 to 16 inches square, if of the form shown in Fig. 62, and from 10 to 16 inches in diameter, if of the form shown in Fig. 63; for ramming molds on the floor, larger sizes are used. Snap flasks may also be oblong or of any other shape desired. Those shown in Figs. 62 and 63 are constructed with clasps and hinges, as seen at *x* and *y*, so that they can be opened and removed from the outside

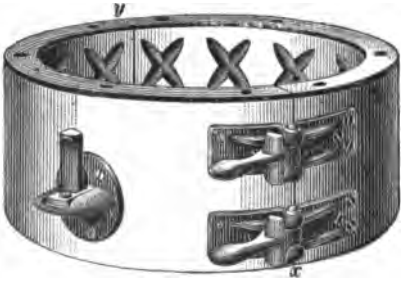


FIG. 63.

of the mold without breaking it; this permits of one flask being used to make any number of molds. It is chiefly molds that have little side pressure when being poured that are cast in snap flasks; for when the flask is removed from the mold (leaving it as in Fig. 69), there is little to prevent the pressure of the fluid metal from bursting the mold outwardly. To prevent snap-flask molds bursting, the molder can place them against one another in rows of ten or more, and then bank up 4 or 6 inches of sand against the outside

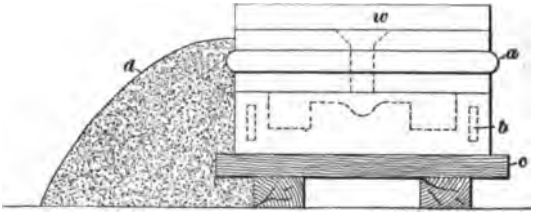


FIG. 64.

of the molds in the outer rows, as at *d*, Fig. 64. If the bottom boards stick out, as at *c*, or the cope has *lifting ridges*, as shown at *a*, sand must be rammed around all the sides not facing the outside, as at *d*, to prevent bursting. Where there are only a few molds on the floor that are liable to burst when cast, some molders when ramming the nowel place loose rings of round or flat iron in the sand to strengthen the mold, as at *b*, Fig. 64. In this illustration, a weight is shown on the flask at *w*, the weight being of the form shown in Fig. 45.

BENCH MOLDING.

ITS ADVANTAGES.

72. In order to save time and labor in making some kinds of small castings, benches of the form seen in Fig. 65 are used. There are many firms that make a specialty of bench molding with snap flasks only. The workmen are called **bench molders.** Some bench molders will make

from 75 to 100 molds per day, according to the size of the flask and the character of the pattern used. There is little skill involved in bench molding compared to that necessary in floor work. The chief skill involved in bench molding generally lies in getting up the pattern and mold board. In some cases, a dozen or more patterns may be attached to a plate or pattern board, and the whole finished in such a manner that as soon as the plate is withdrawn from the mold, the cope can be put in place. While there are

FIG. 65.

many founders making a specialty of bench molding only, there are many large foundries that could utilize benches and snap flasks for making some of their very light castings, instead of molding them on the floor after the manner of heavy work. Not only are benches used for convenience in ramming up snap flasks, but also for the ordinary small wooden and iron flasks, ranging from 12 to 14 inches, square or round. When molding light work upon a bench, the molder can take a convenient position while at work. Also, his tools are always at hand and ready for use, as

seen in Fig. 65, where the sieve, strike, dry brush, sponge and swab pot, blackening or flour bag, parting sand, and place for his rammer are marked *a*, *b*, *c*, *d*, *e*, *f*, and *g*, respectively; his trowel and other finishing tools can also be kept at hand. Such an arrangement of the ramming bench, with shelving on both sides, allows all tools to be within convenient reach and provides a place for everything necessary in ramming and finishing these molds.

RAMMING BENCH FLASKS.

73. In ramming flasks on the bench, two wooden rammers, shown in Fig. 66, are generally used, one in each hand, after the manner seen in Fig. 65. In ramming such flasks, the nowel especially should be peened very solidly around the outer part of the mold, so as to give as much strength as practicable, to withstand the side pressure of the metal on the mold when it is poured. In using a rammer in each hand, as shown, one should be as effective as the other; this requires practice, as in the case of a man learning to shovel both right- and left-handed. After the molder has peened around the outer portion of the mold, the rammers are changed end for end, so that the butt can be applied to finish the ramming. The butting done, a **strike** is used to level off the nowel, ready for the bottom board. This is rubbed down to a good solid bearing and removed for the purpose of venting, if such is necessary, after which the board is returned and the whole rolled over without the use of clamps, the molder holding the boards in place, as seen in Fig. 67. The nowel having been rolled over and the joints made, the cope is then rammed up, lifted off, and set upon the shelf, as seen at *h*, Fig. 68. When the patterns are drawn and the mold finished, the cope is replaced. In Figs. 65 and 68, to show clearly what the molder

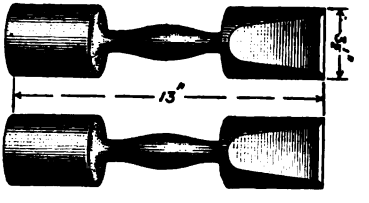


FIG. 66.

is doing, he is shown standing to one side of the bench

FIG. 67.

FIG. 68.

instead of in front—the latter being the proper position when ramming or drawing a pattern.

USING SNAP FLASKS.

74. The flasks having been closed, the clasps at *x*, Fig. 62, are unhinged and the cope and nowel then removed and placed upon the shelf at the left of the ramming bench, ready for making the next mold. The mold is now picked up and carried to its place, as shown in Fig. 69. In placing the first molds on the floor, they are

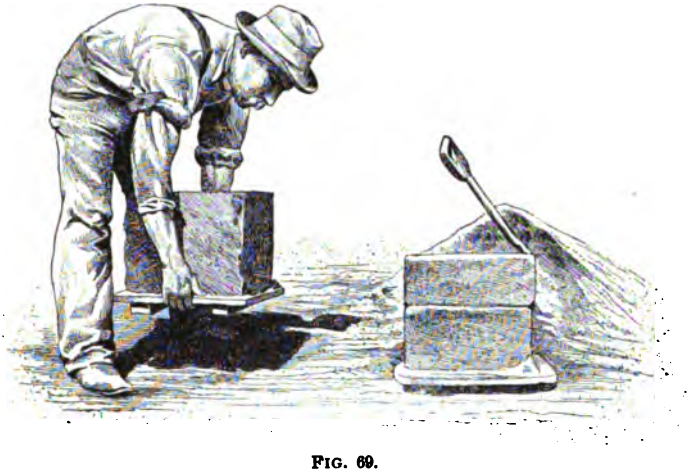


FIG. 69.

carried away as far as necessary in order to have the floor contain the day's work, and sufficient room is left between the bench and the nearest row of molds to cast them. In setting the molds, they should be placed nearly level and as close together as they can be, and then in starting to pour them, those in the front row near the bench are cast first. It generally requires two men to "pour off" a floor. As each row is poured off, the molder's assistant first changes the weight *w*, Fig. 64, to the next row, and then pulls back the row that was poured to leave room for the molder to go between the rows, this process being continued until all the rows are poured off. The pouring having been finished, the molder starts at the front and picks up each flask and carries it to the space for the sand pile near the ramming bench. The bottom boards are piled close by the bench and the castings are pulled from the sand with tongs and placed on

one side in a pile. Occasionally, in shaking out, the molder sprinkles the hot sand with water, so that it may be in good shape for tempering the next morning.

MODERN SHOP EQUIPMENT.

75. The two items to which attention is directed in up-to-date establishments is the use of **power** (other than hand) and the adoption of **molding machines.**

In heavy-work foundries, the advance has been chiefly in the direction of securing shops well arranged, lighted, and ventilated, and the installation of power cranes—operated by electricity, steam, or compressed air—by which one man can often do the work of a dozen. Also elevators are used to raise the stock to the cupola instead of carrying it in wheelbarrows as formerly, power screens and riddles for preparing the sand, and pneumatic rammers for work on large molds.

In light-work foundries, the molding machine is playing an important part in reducing the cost of production. These machines have not replaced hand work entirely, but they are gaining ground. They are made in a great variety of styles, to suit different kinds of work, and are run either by hand or power. As a rule, they produce exact copies of the pattern in work for which they are adapted. They generally save from one-fourth to one-half of the molding labor that would be incurred if made on the bench or floor by hand. These machines save labor chiefly in ramming the sand; much of the other work is the same as it would be without the use of a machine. Some machines, however, have appliances that mix and carry the sand to the flask, leaving the molder only the work of placing and carrying away the flask, together with a little finishing of the mold and setting of the cores.

The five views in Fig. 70 will without further explanation give an idea of hand molding machines.

Fig. 71 is from a photograph; it shows the character of casting that can be made on a molding machine, and also the number that can be made in a flask on one gate.

Not only have machines and mechanical appliances been helpful in light-work foundries, but also for heavy work there are devices that are of much assistance in producing

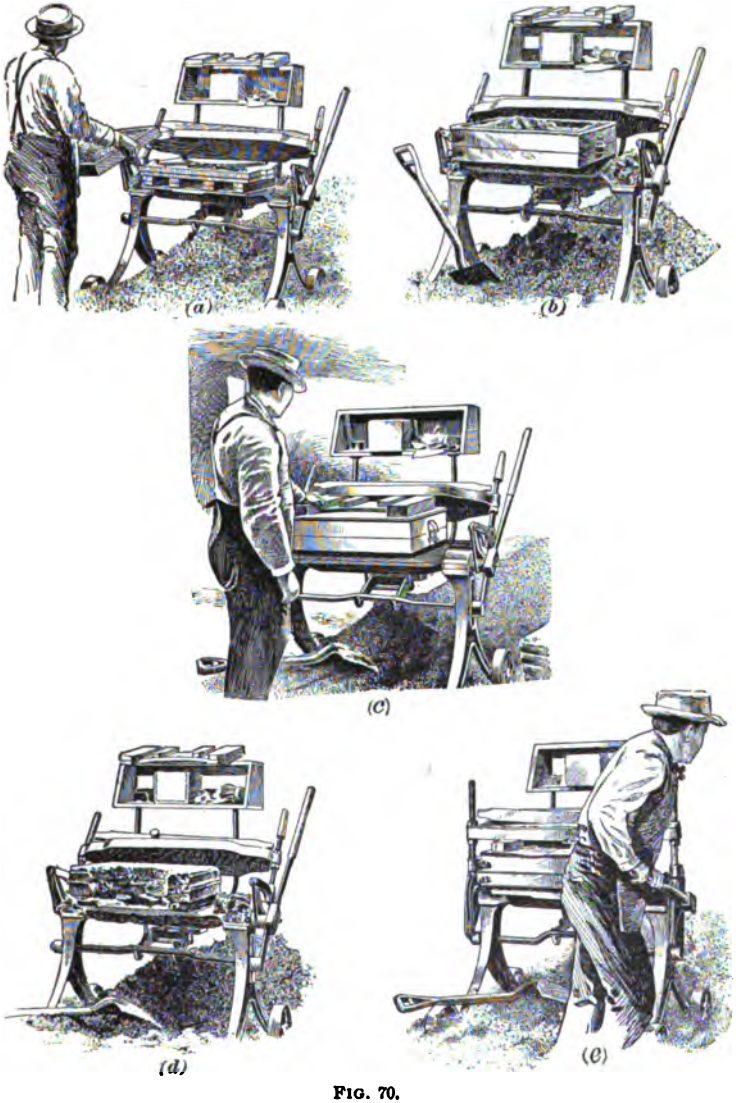


FIG. 70.

greater quantity and better quality of work than could be obtained with hand labor alone. There are few modern

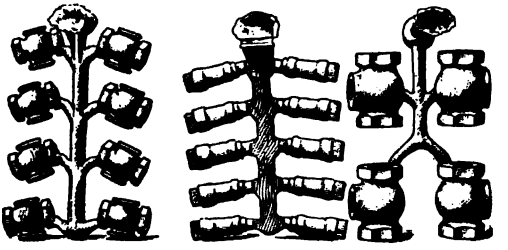


FIG. 71.

shops that are not using some improvements designed for their specialties, which have demonstrated their value.

In cleaning castings, appliances such as tumbling barrels, pickling baths, emery wheels, sand blasts, and pneumatic chippers are now being largely used as improvements over old methods. While one could continue to enumerate special labor-saving devices adopted for special jobs, it is nevertheless true that the greatest improvement in quality and quantity in the production of castings has been due to specializing in certain lines of work; the founder studies to fit up specially for the production of this work and also takes advantage of the constantly increasing proficiency of his workmen, who naturally improve from day to day when restricted to the same kind of mold. The molder who cannot without extra exertion improve in quantity and quality by constant application to one job is a very poor type of workman.

PROTECTING THE MOLD AGAINST FUSING.

COMPOSITION OF SAND AND OF PROTECTIVE MATERIAL.

76. In order to obtain a smooth surface on the casting, it is essential that the sand forming the face of the mold should be well tempered and sieved and—for a large class of work—be mixed with some **protective material** to

keep the sand from **fusing.** Molding sands are composed of silica, with small quantities of lime, oxide of iron, potassium, and magnesia. The three latter elements are easily fused; they combine with the silica to form silicates or a kind of glass that, on heavy castings, may form a scale varying in thickness from $\frac{1}{100}$ inch up to $\frac{1}{4}$ inch, if the face of the mold is not protected with some non-fusible material. The face of the mold may be protected by mixing finely ground **sea coal** with the sand, or by facing the mold with blackening. In some cases a facing sand containing sea coal is used, and this surface is covered with blackening.

Sea coal in America is obtained chiefly from the Youghiogheny River and Cumberland districts and is selected for its gaseous qualities and freedom from slate and sulphur. In addition to mixing sea coal with the facing sand, the surfaces of molds are often covered with what is called **blackening** or **lead.** Blackenings and leads consist chiefly of carbon, the other ingredients being alumina, silica, lime, and iron; the less of these latter elements present, the more intense heat the blackenings and leads will stand before fusing. The cheaper blackenings are composed chiefly of Lehigh coal, coke, gas-house carbon, and charcoal, with the addition of various minerals that contain little or no lead. These blackenings when ground to a powder lack cohesion, and, therefore, they are apt to float or wash before the flow of iron when the mold is being poured. To guard against this, various minerals or clays are ground in the blackenings to give them cohesion. The finer the pure coke or carbon is ground, the more cohesion will it possess; and when ground very fine, the cohesion may be sufficient to hold the material together without the use of any bond. Lehigh blackenings are made by grinding to a dust fine qualities of Lehigh coal. Coke blackenings are made from good grades of coke, selected from a grade having the highest fixed carbon, which at times runs as high as 90 per cent. Gas-house carbon being practically a pure carbon, makes excellent blackening; but, on account of its being a difficult material to grind and bolt, it is not in much favor with

blackening manufacturers. Charcoal, in order that it may make a good blackening, requires to be made from some hard wood, as hard maple, and to be carefully burned. Soft or stringy-grained wood is not well adapted for making charcoal blackenings.

Graphite is recognized as being the most non-fusible material used for blackening. The best grade of imported graphite comes from the island of Ceylon. In its crude state it looks like bright chips of burnished silver, from which fact it is commonly called **silver lead.** This grade of graphite is not only very valuable for mixing with blackenings intended for green-sand, dry-sand, and loam work, but it is also good to dust in a dry state over the surface of molds, as it assists in sleeking the mold and peeling the casting. Of recent years, graphite has been extensively used in many foundries. In putting it on a mold, many molders use camel's-hair brushes, while others will shake it out of a bag, as seen in Fig. 34, or throw it on by hand. High grades of graphite excel all other blackening in **peeling** a casting and giving it a fine, smooth face, and bright color. Some grades of graphite are procurable in this country. North Carolina produces some graphite, but it is mixed largely with clay and other foreign substances. Graphite is also found in eastern Pennsylvania and Tennessee, but the best grade comes from Ticonderoga, New York.

PREPARING THE FACING SAND.

77. Percentage of Sea Coal.—As a rule, the heavier the casting, the more sea coal is required in the facing, the limit being 1 part of sea coal to 6 parts of sand. If more sea coal than this is used on any casting, it is very liable to make the surface streaked or veined, especially in heavy work; although where the molds are heavily coated with good graphite, or are poured with dull iron, this will not be so pronounced. Facing sand, if made too strong in sea coal, will prevent light castings running sharply, and is very

apt to cause **cold shuts** (this term refers to the condition induced when two bodies of fluid metal run together but fail to unite), or else make the surface of the casting harder than if a weaker facing had been used; this is due to the gas that sea coal generates when the mold is being poured. This gas is liable to create a cushion between the mold and the metal; and the amount of cushioning depends on the speed of pouring, the amount of pressure, and the fluidity of the metal. Where the facing sands are strong in sea coal and the castings are poured "dull," the metal often becomes set before the gas cushions are all destroyed. This has the effect of preventing the metal from running into the corners and edges of the mold and may also cause cold shuts. Then again, these gases may make smooth, concave indentations in castings, as seen at *w*, Fig. 55. Another effect sometimes produced by sea coal is the coating of the surface of the castings with what might be termed coal soot. However, for this to take place to any great extent requires a combination of conditions that seldom exists. While the objectionable conditions described are usually to be found in light- and medium-weight castings, still, heavy castings, when poured with dull iron, may also present some of them.

The proportion in which sea coal is mixed with sand ranges from 1 in 20 up to 1 in 6. Castings under $\frac{1}{4}$ inch in thickness seldom require any facing sand. Below $\frac{1}{4}$ inch thickness, better and smoother castings (that cannot be poured quickly) are often obtained by using common heap sand, well tempered and sieved finely on the patterns. In general, castings from $\frac{1}{4}$ inch to 1 inch thick require facing sand having 1 part of sea coal to 12 parts of sand; above 1 inch and up to 2 inches, 1 part sea coal to 10 parts sand; from 2 inches to 4 inches, 1 part sea coal to 8 parts sand; all above 3 inches in thickness, 1 part sea coal to 6 parts sand. In mixing facing sand, some molders use common heap sand, or old sand mixed with new in varying proportions, according to the strength of the different sands.

It is not always the thickness of the casting that regulates the strength of the facing sand. There are many other

things to be considered: (1), whether the casting is to be poured with hot or dull iron; (2), the distance of some parts of the mold from where the metal enters; (3), the time it will take the mold to become filled with iron; (4), whether the metal is running over flat surfaces, and, (5), is covering them slowly or quickly. Then again, heavy solid castings have become "cold shut" owing to the use of facings that were weak in proportion to the thickness of the casting, caused by the slow rising of the metal in pouring the casting. Strong facings on the sides of a mold, where the iron runs in and rises slowly, may easily cause heavy castings to be "cold shut." Again, the square corners of castings should, generally speaking, have weaker facings on them than the straight plain surfaces, and the lower parts of high molds should have a stronger facing than the upper portion; since, if the strong facing suitable for the lower portion were used at the upper, the casting at the upper part would be curly or partly cold shut at the surface, owing to the dulness of the metal when it reached the upper portion of the mold. A new sand without mixture will require more sea coal than if it were mixed with old or common heap sand.

Where molds are long in preparation, or are to withstand rough usage in drawing the patterns, it is best, if there are no conditions prohibiting it, to use new sand in mixing the facings. For copes covering heavy castings, it is best to use all new sand. For light-work copes that cover flat surfaces it is best, when the new sand is strong, to use some old sand with it—in equal proportions sometimes.

78. Thorough Mixing Necessary.—It is not uncommon to find castings streaked, veined, cold shut, or not peeled, because the sea coal in the facing had not been thoroughly mixed with the sand. When castings are very massive, as great a percentage of sea coal as possible is mixed with the sand, in order to peel the casting. Much more sea coal can be added to some sands by thorough mixing than would be otherwise possible. In some cases it

may be possible to mix facings for massive castings with as high a proportion as 1 part of sea coal to 5 parts of sand, providing the sea coal is thoroughly mixed with the sand. A good way to mix facing sands thoroughly is to tramp them with the feet for from 2 to 4 **cuttings** or "turnings over" of the sand, and then at the last cutting to riddle it through a $\frac{1}{2}$-inch riddle and then through a $\frac{1}{4}$-inch one, and finally through the sieve before applying it to the face of the pattern. In cutting the sand, it should be well scattered, as shown in Figs. 2 and 3, *Foundry Work*, Part 1.

FOUNDRY WORK.

(PART 3.)

CORE MAKING.

GREEN-SAND, DRY-SAND, AND LOAM CORES.

1. Cores are bodies of **green-sand, dry-sand,** or **loam,** generally made separately from the molds and placed in them to form such interior openings or holes in the castings as cannot be economically or safely formed directly with the pattern. It generally requires greater experience and skill to make cores in green sand than it does in dry sand.

2. The cores for many castings can advantageously be made of green sand, especially when a large number of castings must have their core sections uniform in size. This will be better understood when it is considered that dry-sand cores, especially large ones, are liable to sag or change their shape in drying the sand, whereas green-sand cores remain the size of the box in which they were made. Another advantage of green-sand cores lies in their permitting the making of thinner castings of pipes, etc. than can be made with dry-sand cores, especially in the larger sizes. Where there is danger of the gates cutting or scabbing, or where the casting is massive in its proportions, it is safer, as a rule, to use dry-sand or loam-work cores; this is also true of intricate shapes, or when it is difficult to vent a core.

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